THE ANTISEPTIC SYSTEM:

A TREATISE

ON

CARBOLIC ACID AND ITS COMPOUNDS;

WITH

ENQUIRIES INTO THE GERM THEORIES OF FERMENTATION, PUTREFACTION, AND INFECTION; THE THEORY AND PRACTICE OF DISINFECTION; AND THE PRACTICAL APPLICATIONS OF ANTISEPTICS, ESPECIALLY IN MEDICINE AND SURGERY.

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TO

MY FRIEND

AND

ESTEEMED TEACHER,

LIONEL S. BEALE.

CONTENTS.

PREFACE.

THERE is, I am well aware, a danger that one who writes concerning a single agent, however valuable, shall be written down an enthusiast. I trust, however, that the intrinsic evidence of this work will show that I have approached my subject in the spirit, not of an advocate, but of an enquirer. The extensive and numerous applications of Carbolic Acid in the Arts, and the fact that no book devoted to a consideration of its action has yet appeared in this country, afford, I think, a sufficient apology for the appearance of this volume. In my investigation I have been largely indebted to the work of M. LEMAIRE; the knowledge of this, which contains 745 pages and dates from 1865, has been confined to but a few observers here. I have accepted M. LEMAIRE'S conclusions in many, but not in all cases; whenever it has been possible I have applied the test of independent investigation.

As I have said, I am no apologist for the agent on which I write. I have rather regarded it as the key which I have found to unlock a cabinet which has been difficult to open. I do not pretend that other keys will not fit the lock, nor that the cabinet may not be opened by more forcible means.

I have entered at some length into the consideration of the Germ Theory of Fermentation and Putrefaction, with the

collateral enquiry concerning the Origin of Life, because it is of the greatest importance in relation to the questions of the Causation and Treatment of Transmissible Diseases, which depend upon its exposition. There is no doubt that the Germ Theory has met with strenuous opposition from members of the medical profession whose ability is well known and whose opinions have just weight. I have a vivid recollection of a debate at one of the medical societies, in which I was, in defence of the Germ Theory, one against a multitude. It would at first sight appear strange, that whilst many of the most illustrious of chemists—cultivators of a precise science—investigate, accept, and promulgate the Germ Theory, and explain many chemical phenomena by its means, those who apply practical science to biology—the nature of whose studies precludes finality in conclusions—repudiate it as a chimera. There is no doubt that a reasoning and enquiring scepticism in matters relating to the science and art of Medicine is very laudable; but those who refuse belief should at least be acquainted with the data on which the theory they contest is based. I think I am right in the view, that in the case of the Germ Theory, these data are imperfectly known, and there are many reasons for this imperfection of knowledge. The laborious researches of PASTEUR, and the close reasoning which he has founded upon them, have been presented in a disjointed and fragmentary manner. One who would make himself acquainted with them must laboriously search through the "Comptes Rendus" and the journals of French Science. The illustrious chemist has not collected his works for the benefit of the student and the practitioner. His opponents, on the other hand, are trumpet-tongued; and in the pages of M. POUCHET's work on Spontaneous

Generation, one may read almost all that can be said *against* the Germ Theory, whilst M. Pennetier, the docile follower of Pouchet, has presented the same arguments in a practical form, and in language interesting and forcible, if not convincing. So the medical mind has had the *contras* more vividly impressed upon it than the *pros*. At the first glance, too, it might appear that the hypothesis of the abundant existence of matter in the living state rendered necessary by the Germ Theory makes too great a demand upon credulity; but the dilemma must not be forgotten—the alternative is belief in Spontaneous Generation. I fancy that many who oppose "Germs," would hesitate before subscribing to "Heterogeny." "Under which King, Bezonian?" In the controversy which has taken place, the evidence has been usually presented from partial sources, and one or two experiments have sometimes been triumphantly adduced, as if they could of themselves establish or destroy the Theory. I have endeavoured to assemble the evidence (much condensed and with much of imperfection) from all points, and to obtain a fair and legitimate inference.

The Germ Theories of Fermentation and Putrefaction, of Infection and of Suppuration, and the practical issues from them, have never been hitherto, so far as I know, woven into a coherent whole. Convinced that they are intimately connected, I have presented them as with a bond of union between them; but I am well aware that many who adopt the theory in certain of its applications refuse to adopt it in others, and repudiate it as a whole.

In that portion of my work which treats of Infection, I have greatly to acknowledge my indebtedness to Dr. Beale, not only in regard to the mine of research whence I have dug, but also for enabling me to give a more intelligible

exposition by lending me many of his beautiful engravings. I am afraid that I have sometimes done an unwitting injustice to him by adopting a scheme framed only for the elucidation of my subject without reference to chronology. The discovery of living particles in vaccine was made by Dr. BEALE in 1864, long before the researches of CHAUVEAU asserted the same fact. The mode of production of the pus-corpuscle and its histological characteristics were demonstrated before the College of Physicians in April and May, 1861. It must be unnecessary to state how deeply Science is indebted for the numerous and elaborate works of Dr. BEALE. As regards the nature of the causes of Infectious Disease, it will be seen that I go with him to his penultimate but not to his extreme conclusion. Whenever I have criticised his deductions, Dr. BEALE will, I know, interpret the criticism only as the earnest and sincere endeavour of his pupil to arrive at the truth.

From a review of all the facts and observations I have been led to enunciate the theory *that the poisons of spreading diseases are extremely minute living organisms, having the characteristic endowments of vegetable growths, analogous to the minute particles of vegetable protoplasm whose function it is to disintegrate and convert complex organic products, owing their specific properties in the special diseases, not to any botanical peculiarities, but to the characters implanted in them by the soil in which they first sprang from innocuous parents, and from which they are transmitted—this soil (except in the case of their earliest origin) being the fluids of the animal body.* One who would see an excellent summary of *primâ facie* evidence in favour of the vegetable origin of disease germs should consult a paper by the late Dr. CHARLES DAUBENY, "On the Influence of the Lower Vegetable Organisms in the Production of

Epidemic Diseases," in his published Miscellanies, vol. ii, p. 55.

That such a doctrine has a practical importance I hope and believe. If the hazy hypothesis of occult organic principles as causes of disease be swept away I believe that much good will be done; disinfection will have an intelligible connotation, and it is possible that the treatment of disease will stand upon a firmer basis.

The agents which I have had the satisfaction of introducing into Therapeutics will, I trust, prove valuable. I have received a large amount of testimony to their usefulness. I would not have it thought, however, that I place an exaggerated value upon them or conceive them to be the *summa bona* of means for the treatment of infectious disease. I well know that there are cases of deadly infection in which all treatment is hopeless. Many persons assert the utter powerlessness of drugs in all infectious diseases, and adopt a treatment entirely expectant. I believe the conclusion and the practice founded upon it erroneous. If but one life in a thousand can be saved there are a gain in the present and a promise in the future. My experience of the sulpho-carbolates in infectious diseases has been favourable, but that experience is necessarily limited and imperfect. Beyond a natural interest in the enquiry concerning them, the sulpho-carbolates are nothing to me; of far higher significance is the hope that this volume may be of some interest and practical usefulness.

A. ERNEST SANSOM.

DUNCAN TERRACE,
June, 1871.

THE ANTISEPTIC SYSTEM.

CHAPTER I.

CARBOLIC ACID: SKETCH OF THE HISTORY OF ITS EMPLOYMENT.

Carbolic Acid, otherwise called phenic acid, phenol, phenyl alcohol, or coal-tar creasote, is a compound of carbon, hydrogen, and oxygen, which is variously regarded by chemists as an acid or an alcohol. It is sufficient for our present purpose to state that it is one of the most important ingredients of ordinary coal-tar. An attempt to trace the history of its employment must commence at the records of remote ages.

Compounds containing carbolic acid, or substances closely allied thereto, are widely spread over the globe. Besides the varieties of coal which yield it in varying proportions, there are bitumen, asphalte, and petroleum in vast quantities on the earth's surface—compounds in which exist close allies of carbolic acid in nature and in properties. Bituminous compounds were used by the Egyptians for the purpose of embalming their mummies—an early instance of their antiseptic employment. Tar was burnt as a means of fumigation. Similar compounds were also employed for another purpose—to arrest fermentation. The Romans sometimes placed their fermenting wine in vessels lined with pitch, or threw powdered pitch into the fluid, or

adopted the simple expedient, the *rationale* of which was probably identical, of plunging therein a blazing pine torch. There is no doubt that carbolic acid in the guise of tar formed part of the *conditurœ* and *medicamina* which thus controlled the vinous and prevented the acetic fermentation. Pliny mentions liquid pitch as used to preserve the wood of ships, casks, &c. According to Dioscorides, naphtha and petroleum were used for analogous purposes.

It is needless to observe how commonly tar has been used in succeeding ages to coat any wooden structures exposed to air and moisture. Tar has been much used both as an internal remedy and as an external application.

In 1834 Runge obtained from coal-tar pure carbolic acid. He is the undoubted discoverer of the agent, and he experimentally demonstrated its powerful disinfecting properties.

Carbolic acid is the active principle of pitch-oil and oil of tar, just as quinine of cinchona-bark, strychnine of nux-vomica, or morphia of opium.

It is important here to state the relation subsisting between coal-tar oil, or crude carbolic acid, and creasote. At the time of which we are now treating, the two substances were used without any clear distinction being observed between them, and even now much of the creasote of commerce is really an impure carbolic acid. True creasote, however, discovered by Reichenbach, is a totally distinct body. Creasote is, according to Hlasiwetz, an ether of creasol, which latter has the formula $C_8H_{10}O_2$. It does not crystallise like carbolic acid, but is a colourless highly refractive fluid. If creasote be agitated with a little water, and a few drops of solution of perchloride of iron be added to the fluid, a deep olive-green is struck. Carbolic acid similarly treated yields a beautiful mauve tint. Both these bodies are powerful antiseptics.

In 1844 M. Bayard introduced a powder in which coal-tar was an ingredient, which he employed with much success as a disinfectant.

In 1851 Mr. Calvert, of Manchester, made many experiments with carbolic acid. It was used for preserving flesh

from putrefaction ; it was injected into the arteries of dead animals, and thus served to prevent putrefaction, and it was found to check fermentation. About 1859 it occurred to M. Le Beuf, of Bayonne, to employ the then crude carbolic acid in the form of a saponaceous emulsion. He joined in the work M. Lemaire of Paris, who has made it the starting point of a laborious research. The two investigators sent to the Academy of Medicine a note on the value of the emulsion as an application to gangrenous ulcers.

About this time, also, Küchenmeister, of Dresden, investigated the action of carbolic acid. He used it in medical and surgical practice, and in arresting putrefaction and preventing the manifestation of fungi.

Continuing his investigations on coal-tar applications, M. Lemaire, in 1860, established their value in the treatment of wounds, and demonstrated that carbolic acid was the active agent in effecting the changes. M. Lemaire, in an elaborate treatise, first published in 1863, narrated a long series of investigations in which carbolic acid was employed as a means for the destruction of low forms of animal and vegetable life, as a preventive of fermentation and putrefaction, as an external application in cases of ulcerating and suppurating surfaces, as well as an internal remedy in zymotic and other diseases. Concurrently with the study of carbolic acid as a disinfecting agent, investigations were being made as to its use in the arts. Laurent, in 1841, demonstrated the production of picric acid from the action of nitric upon carbolic acid. Picric acid is much used as a yellow dye, and from it are derived picramic acid and isopurpurate of ammonium, yielding rich brown and garnet hues. Picric acid has been administered as an internal remedy in intermittent fevers.

The occurrence of cattle-plague in England in 1865 gave an impetus to the study of disinfectants, and the subject received considerable elucidation by the investigations of Dr. Angus Smith and Mr. Crookes. Their results are embodied in the "Report of the Commissioners, 1865." During the outbreak of cholera in 1866, carbolic acid was put to a further practical test, and the reports of many of

the medical officers of health testified to its efficiency. These records may be found in the Registrar General's Report on the cholera epidemic of 1866 in England. In 1865 Professor Lister, who seems scarcely to have been aware of M. Lemaire's prior observations in exactly the same direction, commenced the employment of carbolic acid as an application in surgical cases attended with suppuration. Professor Lister gave much precision to the method of treatment; and, in his communications to the "Lancet," of March and July, 1867, he detailed remarkable cases showing its good results. Compound fractures of extreme danger to life as well as limb were observed, when dressed with carbolic acid skilfully applied, to recover with the occurrence of the slightest possible suppuration, and the general condition of the patient, especially in relation to the reactive fever, contrasted very favourably with that which exists under any other condition or plan of treatment. Professor Lister also employed an external dressing of the agent to prevent suppuration after the opening of large abscesses.

More recently, Professor Lister recommended the use of ligatures impregnated with carbolic acid, for the deligation of arteries in the living body; and his observations show that in cases treated in this way recovery takes place in a very satisfactory manner, with the formation of scarcely any pus. The employment of carbolic acid in surgical practice subsequently became very general, and the medical journals contain a large number of communications testifying to the success of the treatment. The plan was also tried in most of the metropolitan hospitals. Evidence exists, however, to indicate that the plan is not uniformly successful; and there are sufficient data to show that for a prospect of good results attention must be paid to points of detail.

Much of the apparent discrepancy in individual experience can, I believe, be explained by a study of the chemical characteristics and the pathological influence of the agent. The investigation is yet in its infancy. The following pages will contain an attempt to elucidate some of the therapeutical problems.

CHAPTER II.

CHEMISTRY OF CARBOLIC ACID AND ITS PHARMACEUTICAL MANIPULATION.

Carbolic Acid, C_6H_6O, or C_6H_5OH, presents in composition and properties strong resemblance with the alcohols. It is classed under the secondary aromatic alcohols, and in this connection it is termed phenol. It has no acid reaction to test paper, but it forms with bases distinct and definite salts.

Preparation.—It may be obtained by the dry distillation of salicylic acid, either alone or mixed with pounded glass or with lime or baryta. The salicylic acid is wholly converted into carbonic acid and carbolic acid.

$$\underset{\text{Salicylic acid.}}{C_7H_6O_3} = \underset{\text{Carbonic acid.}}{CO_2} + \underset{\text{Carbolic acid.}}{C_6H_6O}$$

The chief commercial source of carbolic acid is coal-tar oil. The crude product is shaken with lime and water; after a considerable lapse of time the watery portion is decanted, decomposed by hydrochloric acid, and the oily product distilled. The portion (to the extent of one-third) which first passes over should be alone collected.

Or the coal-tar oil may be distilled, and the distillate which passes over between 150° C. (302° F.) and 200° C. (392° F.) collected. This should be mixed with a hot strong solution of caustic potash, together with a little of the alkali itself. A crystalline mass forms, which, being dissolved in water, separates into an oily stratum and a denser sub-stratum; the latter is separated, its alkalinity neutralised by hydrochloric acid, and the oil which becomes liberated collected. This should be distilled with chloride of calcium and then exposed to a low temperature, when carbolic acid crystallises out.

Cannel-coal is the variety the tar of which yields carbolic acid in the highest proportion, whilst Boghead yields it in the feeblest.

It is probable (according to Gladstone) that contact for some days with a lump of chloride of calcium induces the

conversion of some of the cresylic products present in crude carbolic acid into pure carbolic acid. This affords a good means of purification of the commercial product, the carbolic acid being crystallised out at a low temperature.

Carbolic acid is also produced by the action of nitrous acid on aniline. It has been obtained during the dry distillation of benzoin, of quinic acid, of the resin of *xanthorrhœa hastilis,* and of castoreum. Stœdeler discovered it in appreciable quantities in the urine. It has been prepared by M. Berthelot by passing the vapour of alcohol or acetic acid through a porcelain tube heated to redness. Pure carbolic acid crystallises in long, clear colourless prismatic needles. Its specific gravity is 1·065. The crystals melt at 33° to 35° C. (90° to 95° F.) into a colourless liquid, oily in appearance and to the touch, which also, when dropped on paper, produces the same appearance as that produced by oils. It boils at 180° C. (370·4° F.)

Mixture with Water.—The crystals of carbolic acid readily absorb water from the atmosphere and become converted into the oily substance before-mentioned. In dispensing and for general use in medicine it is convenient to employ the liquefied acid. It is important to note that this is not a solution, but the pure acid containing a trace of humidity; if there be an excess of water, this is seen to form a clear layer above the denser oily carbolic acid. The fluidity of carbolic acid depends greatly on the temperature.

At 95° F. carbolic acid crystals always melt; at from 65° to 70°, an excess of moisture in the air keeps it fluid. It preserves its crystalline character at 40°.

An excess of humidity at all temperatures promotes the liquefaction of carbolic acid. I have found that it is rendered fluid at and above 48° F. by the presence of about one-fifth of its weight of water.

Solution in Water.—It was long supposed that carbolic acid was scarcely at all soluble in water. Runge, however, stated that water at 60° F. could dissolve 3·26 per cent of the crystallised acid. According to Lemaire's experiments, water at 59° F. can dissolve 5 per cent of carbolic acid.

This being of importance in regard to medicinal preparations, I have made many observations to verify the point. From a series of volumetric observations, I find that at a temperature of 65° F., 4·8 c.c. will dissolve in 100 c.c. of water; at 70° F., 5·4 c.c.; and if the process of solution be prolonged for above seven days, the temperature of the air varying from 60° to 70° F., 6·4 c.c. will dissolve in 100 c.c. Practically a saturated aqueous solution of carbolic acid contains very nearly 5 per cent.

Mixture with Alcohol and Ether.—Alcohol and ether freely dissolve carbolic acid. A small proportion of alcohol keeps carbolic acid in the fluid condition. It is convenient for ready employment under many circumstances, and particularly in dispensing carbolic acid as a medicinal agent, to have the pure acid in a fluid state. This avoids the necessity of weighing the deliquescent substance or the application of the heat necessary to liquefy it.

I have already mentioned the proportion of water necessary to preserve it in the fluid state. Lemaire advocated the employment of alcohol mixed with the carbolic acid in equal proportions as a means of rendering it permanently liquid; but I have found that a proportion of one part of the former in sixteen of the latter is sufficient at ordinary temperatures.

Agents supposed to Increase the Solubility of Carbolic Acid in Water.—Lemaire says that the normal solubility of carbolic acid can be increased "in notable proportions" by the addition of 5 or 10 per cent of alcohol or acetic acid. I have investigated the influence of the following admixture:—

1. *Alcohol.*

(*a*) Carbolic acid being mixed with one-fifth its bulk of absolute alcohol and water, added in excess 4·2 c.c. dissolved per cent.

(*b*) Carbolic acid and alcohol being mixed in equal parts, and water added, a perfectly clear and uniform solution can be made of 21 c.c. per cent. The addition of more water, however, produces a

milkiness which, as still more is added, becomes a dense whiteness. On agitating and afterwards allowing the mixture to stand, some undissolved oily carbolic acid sinks to the bottom of the solution.

The white appearance seems to be due to the refraction produced by multitudes of minute globules of carbolic acid in suspension. I find that although alcohol and carbolic acid make a perfect solution together, which will bear an addition of water to the extent of 2½ times their united bulk without disturbing the uniformity of the solution, yet that water cannot be made to take up more than 7·4 per cent of carbolic acid by the addition of an equal bulk of alcohol. In such case, too, the supernatant fluid is milky and presents different densities. I conclude, therefore, that the presence of alcohol, though it favours the distribution of carbolic acid does not materially increase its actual solubility.

2. *Acetic acid* forms with carbolic acid a perfectly clear solution, and when mixed in equal bulks, the combination appears to be soluble in distilled water in all proportions.

3. *Glycerine.*—Carbolic acid crystals easily dissolve in an equal bulk of glycerine. The *glycerinum acidi carbolici* of the British Pharmacopœia is in the proportion of one to four.

The combination of carbolic acid with glycerine when mixed with water behaves in much the same manner as that with alcohol. Thus, in case of equal proportions, water may be added to the extent of five times the quantity of carbolic acid employed with the effect of producing a perfectly clear solution. On the further addition of water, however, it will be found that a similar whiteness to that appearing in the case of alcohol occurs with subsequently a subsidence of carbolic acid. The proportion actually dissolved is then but 5·5 per cent, or not more than is dissolved by water without the addition of glycerine.

Mixture with Oil.—Carbolic acid crystals dissolve, becoming very bright and glistening in the process, in about their own bulk of olive oil. The result is a limpid oily compound paler than the oil employed. Agitated with water, this forms a white, apparently homogeneous emulsion, which on

standing, separates into three layers—(1) clear oil; (2) turbid oil; (3) white emulsion, with some oil globules.

Tests of the Presence of Carbolic Acid.

1. The test recommended in the "British Pharmacopœia" is the colour imparted to a slip of pine wood dipped into the fluid, and afterwards into hydrochloric acid. "A slip of deal dipped into it, and afterwards into hydrochloric acid, and then allowed to dry in the air, acquires a greenish blue colour." I have found this test neither delicate nor reliable.

2. A few drops of a solution of a per-salt of iron (the perchloride is usually employed) added to a neutral aqueous solution of carbolic acid develope a beautiful mauve colour, comparable only with that of a solution of an alkaline permanganate. I have found this give a distinct indication of the presence of a one-to-one-thousand dilution of carbolic acid.

3. If to an aqueous solution of carbolic acid in a test-tube there be added a small quantity of hypochlorite of lime (or, better, a little of its solution), and then a few drops of strong liquor ammoniæ, and the whole be heated to nearly boiling, a beautiful blue colour is developed. This was, I believe, first observed by Berthelot.

4. The fourth test is a modification and reversal of my own of Day's test for mucus. To a little of the clear aqueous solution, supposed to contain carbolic acid held in a test-tube, is added a small quantity of saliva from the mouth. After agitation, two or three drops of alcoholic tincture of guaiacum, previously exposed for a considerable time to the air, so as to be freely oxidised (*i.e.* until it turns green on the addition of iodide of potassium), are added. The mixture then assumes a bluish-green hue. A collateral experiment with pure water, instead of the carbolised solution, should always be made, and the test then is an extremely delicate one.

Carbolic acid reduces mercuric oxide, at a boiling heat separates silver from the nitrate, and heated with arsenic acid forms a yellow xantho-carbolic acid.

Tests of the Purity of Carbolic Acid.

(*a.*) The crystalline acid. The crystals should be perfectly clear, colourless, and homogeneous. They should melt at a heat of 34° C. (93·2° F.), and the liquefied product should boil at 184° C. Distillation should be carefully conducted at this temperature; any product remaining in the retort will indicate impurity.

(*b.*) The acid in the liquid form. The liquids purporting to contain carbolic acid for use as disinfecting agents are frequently admixtures of tar oils with caustic alkalies. Thus the compounds submitted to Mr. Crookes were shown to consist of—(1) Alkaline water, with tar oils boiling above 370° C., and, therefore, containing *no* carbolic acid; (2) tar oils containing feeble proportions of carbolic acid (2·6 to 5·9 per cent); (3) tar oils with a notable proportion of carbolic acid (30 to 50 per cent); (4) tar oils containing fœtid sulphur compounds; (5) compounds containing sulpho-carbolic or sulpho-cresylic acid soluble in water.

Mr. Crookes pointed out a ready method of detecting the adulterations by observing the solubility of a given sample:*

"Commercial carbolic acid is soluble in from 20 to 70 parts of water, or in twice its bulk of a solution of caustic soda, while oil of tar is nearly insoluble; but if the amount of carbolic acid be increased some remains undissolved.

"To apply the tests:—1. Put a teaspoonful of the carbolic acid in a bottle, pour on it half-a-pint of warm water, and shake the bottle at intervals for half-an-hour, when the amount of oily residue will show the impurity. Or, dissolve one part of caustic soda in ten parts of warm water, and shake it up with five parts of the carbolic acid. As before, the residue will indicate the amount of impurity.

"These tests will show whether tar oils have been used as adulterants; but to ascertain whether the liquid consists of a mere solution of carbolic acid in water or alkali, or whether it contains sulpho-carbolic or sulpho-cresylic acids,

* Report on the Application of Disinfectants in Arresting the Spread of the Cattle Plague. Reprint, p. 36.

another test must be used, based upon the solubility of these, and the insolubility of carbolic acid, in a small quantity of water. In this case proceed as follows:—2. Put a wineglassful of the liquid to be tested in a bottle, and pour on it half-a-pint of warm water. If the greater part dissolves, it is an adulterated article. Test the liquid in the bottle with litmus paper; if strongly acid it will show the probable presence of sulpho-acids, whilst if alkaline it will show that caustic soda has been probably used as a solvent.

"These tests are not given as having any pretensions to scientific accuracy, but as affording persons who are desirous of using carbolic acid, and are willing to pay a fair price, a rough and ready means of seeing if they are being imposed upon.

"If greater accuracy in the tests are required, recourse should also be had to distillation with a thermometer—carbolic acid boils at 184° C., cresylic at 203° C., whilst xylic acid, which may possibly be present, and has great antiseptic value, boils at 220° C. Reichenbach's pure creasote boils at 219° C."

The strength of a chemically pure sample of liquefied carbolic acid may be readily estimated by agitating a given quantity with water in a graduated tube, and observing the bulk of carbolic acid subsiding undissolved. This will indicate all over the 5 per cent which dissolves in the water. The total carbolic acid in the sample =

$$\text{Residue} + \frac{\text{superincumbent solution.}}{20}$$

Action on Albumen.—Hydrated carbolic acid has the power of coagulating albumen, forming a white filamentous precipitate. This has been long recognised; and the extent of its coagulating power has been, perhaps, over estimated. Mr. Crookes mixed a one per cent solution of carbolic acid with a solution (1 to 4) of albumen (egg). No change took place for a few minutes, afterwards a slight cloudiness appeared; which ultimately became a coagulum. The clear solution still contained albumen and carbolic acid. My own observations confirm these. A 5 per cent aqueous solution

of carbolic acid added to a 10 per cent solution of albumen of egg produces only an opalescence; a glycerine and water solution of 9·8 per cent produces a similar cloudiness. Similar solutions added to highly albuminous urine produce only a slight cloudiness. In no case was the appearance at all comparable with that produced by a drop of nitric acid.

It may be well to point out a possible source of error. If a solution of carbolic acid in alcohol or acetic acid containing a proportion above that which is nominally soluble in water be employed, a white appearance is produced, exactly like that of precipitated albumen. As before explained, this appearance is due to an aggregation of undissolved particles of carbolic acid.

Carbolic Acid as a Test for Albumen.—M. Méhu* advocated the employment of a reagent consisting of carbolic acid one part, commercial acetic acid one part, alcohol (of 86 per cent) two parts, as a delicate test of the presence of albumen. Dr. Meymott Tidy has advocated a similar method in the "Lancet" of May 14, 1870. Dr. Tidy thus describes his preparation of the test mixture of acetic and carbolic acid:—"I mix equal volumes of the two acids, and then see whether, in adding this to a little water in a test-tube, the liquid after being well shaken becomes perfectly clear. As a rule, I find this proportion is about correct; but if it does not become clear I add a little more acetic acid, trying after each addition until the desired point is reached." A second plan is to add eight or ten drops of alcohol to about two drachms of urine in a test-tube, shaking very gently so as to avoid frothing, and then adding about five drops of carbolic acid from a pipette. In this way it is said that a white precipitate of carbolate of albumen is produced, and the test is so delicate that it will detect one part of albumen in 1500 of water, while nitric acid detects only one in 8000.

I must urge, however, extreme caution in the acceptance of the indications afforded by these tests. I have already

* Journal de Pharmacie et de Chimie, February, 1869.

indicated (and these observations were made by me before those of M. Méhu and Dr. Tidy) the fallacies which surround them. I am prepared to admit at once that hydrated carbolic acid or a strong solution in alcohol or acetic acid will unite with albumen, even when the latter is present in small proportions to produce a white precipitate. But I have found that an appearance absolutely indistinguishable by the eye from that occurring when albumen is present may exist when a solution is perfectly free from albumen.

I have shown that even a saturated aqueous solution of carbolic acid produces but a slight precipitate in an albuminous solution. This appears to be recognised; for the advocates of the carbolic acid test for albumen concur in employing as menstrua for the agent acetic acid or alcohol, which take up very large proportions. The value of alcohol in this relation is, however, set aside by the fact that the superaddition even of pure water causes the subsidence of a dense white cloudy precipitate quite resembling a precipitate of albumen. A similar fallacy I have found to underlie the employment of acetic acid as a menstruum. It is true that the addition of pure water to the aceto-carbolic solution causes no turbidity whatever. I found, however, in experimenting with the test-solution made after Dr. Tidy's formula, that in numberless cases I obtained a white precipitate on the addition of the solution to urine when collateral tests showed the absence of albumen. Moreover, I found it in specimens in which there was no reason whatever to suspect the presence of albumen. In endeavouring to find the reason of this difference in the behaviour of urine and clear water, I first found that if I placed the test solution in a test-tube, and then gradually added the urine thereto, there was always a point during the gradual addition at which the white cloudy precipitate occurred. I then found that a similar appearance was induced when saline solutions were employed. Thus the addition of the aceto-carbolic reagent to an equal bulk of a cold solution of common salt at once developed the white precipitate. The most characteristic appearance was, how-

ever, produced by a saturated solution of tartrate of ammonium. When to about a drachm of the test solution five drops of the ammonium tartrate solution were added, a dense white precipitate fell; when ten drops were added, the whole of the fluid became a dense white solid. There can be little doubt, therefore, that the presence of the saline material reduces the carbolic acid from the solution, and thus causes the appearance which so closely resembles an albuminous cloud.

From these causes, I think, for practical purposes for the detection of albumen in urine, the aceto-carbolic solution is most fallacious. As a confirmatory test it might be useful. In such cases the aceto-carbolic solution should be first introduced at the test-tube, and then a small quantity of urine added. If an *immediate* precipitate appears there is much reason to suspect the presence of albumen.

The albuminous coagula produced by carbolic acid do not undergo putrefaction.

A weak solution of gelatine undergoes no change on the addition of a solution of carbolic acid; a strong solution becomes milky, the milkiness disappearing on the addition of water.

Volatility of Carbolic Acid.—Though carbolic acid requires a very high temperature for ebullition, it is of considerable volatility. This is easily recognised by the extent over which its odour is diffused.

At my request Mr. H. Davison made the following observations:—1. 200 grains of liquefied carbolic acid were exposed in a shallow vessel at ordinary temperatures and weighed at intervals of twenty-four hours. The amount of loss was—(*a*) 10 grains; (*b*) 5·6 grains; (*c*) 5·5 grains.

Pieces of sponge saturated with 200 grains of liquid carbolic acid were suspended in vessels, capacity of 176 fluid ounces, and hermetically sealed for twenty-four hours. At a temperature of 10° C. (50° F.), loss 1·835 grains. Temperature 15·5° C. (60 F.), loss 2·54 grains. Temperature 21·1 C. (70 F.), loss 4·320 grains.

From these data we may conclude that 1 grain of carbolic acid is taken up by

320·75 cubic inches of	atmospheric air	at	10° C.	(50° F.)
159·44 ,,	,,	,,	15·5° C.	(60° F.)
93·75 ,,	,,	,,	21·1° C.	(70° F.)

CHAPTER III.

COMBINATIONS OF CARBOLIC ACID.

Carbolic acid readily unites with many bases, organic and inorganic, but its compounds are usually unstable. It presents in these combinations most of the analogies of an alcohol: it does not, like an aldehyde, unite with the sulphites of alkali metals.

Carbolates.—M. Bobeuf, in 1857, patented a process for preparing the salts of the crude acids of coal-tar with alkali bases. They were chiefly employed for disinfection. These compounds possess an advantage over carbolic acid inasmuch as they are freely soluble, but they are unstable compounds, and appear in their general applications not to be so efficient as carbolic acid itself.

Carbolate of Potassium, $C_6.H_6O,KHO$, in its pure state has been chiefly studied by Laurent, Calvert, and Roméi. It may be prepared by adding together alcoholic solutions of potassium hydrate (56 parts) and carbolic acid (94 parts) and evaporating; or by fusing potassium hydrate (37·4 parts) with carbolic acid (62·6 parts), the former being added to the latter little by little. Carbolate of potassium is thus obtained in white glistening very refractive scales. These soon absorb moisture from the air, and passing through various orange tints become at last deep brown. The crystals fuse between 94° and 95° C. They are very soluble in water and in alcohol, but scarcely

at all in ether. Roméi has employed pure carbolate of potassium to detect water in ether. The dry crystals being added to the ether, if water be present, some solution takes place, and the superincumbent ether becomes tinged reddish brown; $2\frac{1}{2}$ parts of water in 1000 of ether may be thus detected.

Carbolate of Copper, $2(C_6H_6O)3(Cu''H_2O_2)$, is procured by mixing aqueous solutions of sulphate of copper and carbonate of potash. It forms a green powder. *Carbolate of Mercury*, $(C_6H_6OHgO_2H_2)$, prepared in an analogous manner, is a bright orange powder, becoming brick-red in drying; with nitric acid it forms a golden yellow solution. *Carbolates of Barium, of Lead, &c.*, have been produced, but their composition is uncertain.

Carbolate of Quinine, $(C_{20}H_{24}N_2O_2,C_6H_6O)$, forms fine needle-shaped crystals insoluble in water, and scarcely soluble in ether, but readily so in alcohol.

Carbolates of Alcohols are produced by heating potassium carbolate with iodide of methyl, ethyl, or amyl; thus double ethers are produced.

Carbolate of Methyl; Anisol, C_6H_8O, is also formed by the dry distillation of methyl salicylate. It is a colourless, mobile, aromatic liquid, forming a double acid with sulphuric acid, and various substitution products with nitric acid.

Carbolate of Ethyl; Phenetol, or Salithol, $C_8H_{10}O$, may also be obtained by distillation of dry ethyl salicylate of barium. It is a light, colourless, mobile liquid, soluble in alcohol and ether, but not in water. It is agreeably aromatic.

Carbolate of Amyl, Phenamylol, $C_{11}H_{16}O$, is a limpid colourless oil, lighter than water.

Carbolate of Benzoyl, C_6H_5O,C_7H_5O, has been procured as a white, fusible, crystalline compound by treating benzoic chloride with phenol.

Union of Carbolic Acid with Organic Bodies.—It is seen that carbolic acid easily enters into union with inorganic bases, forming definite compounds. It is also easily displaced from its combinations. M. Roméi ("Bulletin de la Société Chimique," Feb., 1869) considers the compounds merely

juxtapositions of the molecules, each constituent preserving unchanged its inherent character. It is important to know whether, in the case of the organic bodies with which the agent may come in contact, it may form compounds which may modify its original properties. It is observed to have a certain affinity for albumen. I shall show, however, hereafter that the presence of a small quantity of potash or of albumen does not impair its power of arresting fermentation.

Does its union with glycerine modify its properties? On this point we have the following evidence—(1) that a mixture of glycerine and carbolic acid acts upon the sensitive surface of the skin as only a very feeble counter-irritant, while a like quantity of the acid mixed with water or with syrup of an equal density with the glycerine solution is a violent caustic; (2) I have shown that the presence of glycerine impairs, in a very obvious manner, the power of carbolic acid to arrest saccharine fermentation. It seems very probable that carbolic acid tends to unite with glycerine, forming a carbolate of glycerine. With olive oil there are (1) a great diminution of the energetic action upon the skin; (2) a very marked impairment of the power of arresting fermentation; (3) also a decided diminution of the property of carbolic acid to arrest putrefaction. A five per cent solution of carbolic acid in olive oil fails to prevent the putrefaction of flesh, though a one per cent watery solution will entirely prevent such decomposition. It is extremely probable that carbolic acid enters into a definite union with fatty matters, modifying its original properties. I have shown that alcohol also lessens its power over fermentation. I think that these considerations are sufficient to show that carbolic acid readily enters into combinations with the organic bodies with which it comes into relation, that these are prone to mutual variations, and that then the original properties of the agent become modified. When, therefore, we employ an aqueous, an oily, an alcoholic, or a glycerine solution of carbolic acid, we are not in each case employing the same identical agent.

Compound Acids and Compound Salts.—Carbolic acid unites with sulphuric to form a definite double acid (*sulpho-carbolic acid*). Sulpho-carbolic acid unites with bases to form an interesting series of salts, which will be described in a subsequent chapter.

Chloro-carbolic Acid.—Chlorine unites with carbolic acid in the following proportions :—

(1). $C_6H_4Cl_2O$, Dichlorocarbolic acid.
(2). $C_6H_3Cl_3O$, Trichlorocarbolic acid.
(3). C_6HCl_5O, Perchlorocarbolic acid.

The first is a volatile oil, insoluble in water; the second forms fine silky needles. This latter has a penetrating odour; it forms well-defined salts. It may be prepared from coal tar, from saligenin, or from indigo. The two latter acids form well-marked metallic salts.

Bromo-carbolic and Iodo-carbolic Acids have also been produced.

Nitro-carbolic Acid.—Nitric and carbolic acids unite in three proportions :—

(1). $C_6H_5(NO_2)O$.
(2). $C_6H_4(NO_2)_2O$.
(3). $C_6H_3(NO_2)_3O$.

The first (mono-nitro-phenol), obtained by distilling carbolic acid with very dilute nitric acid, crystallises in yellow needles.

The second (dinitro-phenol), obtained by the action of ordinary nitric acid, forms yellow prismatic crystals. Its salts are mostly soluble in water.

The third (trinitro-phenol), used in commerce and called picric or carbazotic acid, is produced by the action of strong nitric acid upon carbolic acid, the carbolates, or the sulpho-carbolates. It is also obtained by acting upon indigo, certain resins, benzoin, aloes, silk, or salicine by strong nitric acid. It forms beautiful scales of primrose colour, but slightly soluble in water. Picric acid imparts a deep yellow colour to water; the hue is distinct when it is present only in the proportion of 1 to 10,000, and in feebler proportions in case

of a large bulk. It is much used for dyeing; it colours silk and wool, but not cotton nor flax. Treated with hot solution of cyanide of potassium, it assumes a blood-red colour (isopurpurate of potassium), and this, when chloride of ammonium is added, forms a salt, having all the characters of murexide (purpurate of ammonium). The picrates form a definite series of salts; many of them are explosive and are used for purposes of destruction.

CHAPTER IV.

INFLUENCE OF CARBOLIC ACID ON FERMENTATION AND PUTREFACTION, AND ON THE VITALITY OF LOW ORGANISMS.

The chief value of carbolic acid and the compounds associated with it, a property recognised in the past as well as the present, is that which pertains to it as an antiseptic or an agent preventing putrefactive change. Compounds containing carbolic acid were used in remote ages to arrest alcoholic and to prevent acetic fermentation. It has been proved that minute amounts of carbolic acid arrest the fermentation of saccharine solutions, the formation of butyric acid, the gallic fermentation (*i.e.* the peculiar change of maceration of galls, as in the thickening of ink exposed to the air), and many other varieties of fermentive changes.

Action on Saccharine Fermentation.—A very small proportion of carbolic acid will wholly prevent the fermentation of solution of sugar with yeast placed in the most favourable circumstances for the process.

If the interior of a glass flask be coated by means of a camel's-hair pencil with a little carbolic acid, and then the materials ready for fermentation introduced, and the mouth of the flask closely sealed, fermentation is wholly prevented.

Carbolic acid not only prevents fermentation, but also arrests it when it has once commenced. A few drops added to half-a-pint of actively fermenting sugar at once put a stop to the process.

On the other hand, the presence of carbolic acid does *not* influence the following transformations:—

1. The conversion of starch into dextrine. 2. The formation of essential oil of almonds when amygdalin is mixed with synaptase, as well as the transformations hereafter to be considered as pseudo-fermentations.

I have endeavoured to ascertain the relative power of carbolic acid in arresting saccharine fermentation, and have arrived at the results which are comprehended in the following table :—

Quantities of various agents which will wholly arrest the fermentation of 25 *grains of cane sugar.*

	Grains.
Perchloride of mercury	0·03
Hydrated sulphuric acid	0·10
Carbolic acid	2·00
Perchloride of iron	3·90
Carbolate of potash	4·00
Sulphite of soda	5·00
Sulpho-carbolate of soda	20·00

The experiments which determined these results were strictly comparative; all the solutions placed for fermentation being in precisely similar conditions. It is thus seen that though carbolic acid holds a high place, it is far from being comparatively the *most* efficient agent in restraining fermentation.

I next endeavoured to ascertain whether the presence of oil, glycerine, &c., modified the power of carbolic acid to restrain saccharine fermentation. To this end, I proceeded in this manner. I procured a series of bottles, each of exactly the same capacity; every bottle was fitted with a cork, through the centre of which passed a tube of small bore, reaching in the interior nearly to the bottom. Into

each bottle were placed exactly the same quantities of the fermenting materials. One was left without further addition (A); to another was added half-a-drachm of a 5 per cent solution of carbolic acid; in another, the same quantity of carbolic acid was mingled with 5 minims of pure glycerine; in another, 5 minims of olive oil; in another, 5 minims of alcohol. Water being now poured in so as to fill each bottle, the corks and tubes were fitted, and the bottles simultaneously plunged into a water-bath, at a temperature of 100° F. It is obvious that the conditions in each case must have been precisely identical. On the occurrence of fermentation, the carbonic acid rising to the upper part of each bottle displaced the fluid contents, which escaped through the upper orifice of the glass tube. Fermentation rapidly occurred in the tube which contained the fermenting materials alone, and at the end of an hour this was nearly empty. At the end of seventeen hours the corks and tubes were removed. Of course, the amount of displacement of fluid indicated the comparative amount of fermentation which had taken place. The bottles were then filled up from a graduated burette. I have satisfied myself by a large number of observations that this method of experimentation gives most precise results.

Quantities of carbonic acid evolved; or comparative rate of fermentation when some organic bodies are present with carbolic acid in fermenting fluids. 25 *grains of sugar and* 1 *fluid drachm of yeast used in each case.*

	Carbonic acid evolved.
A. Sugar and yeast alone	total quantity.
B. Sugar and yeast, with 30 minims of 5 per cent solution of carbolic acid	10·4 c.c.
C. Sugar and yeast, with 5 minims of alcohol and carbolic acid as in B	15·6 c.c.
D. Sugar and yeast, with 5 minims of glycerine and carbolic acid as in B	16·8 c.c.
E. Sugar and yeast, with 5 minims of olive oil and carbolic acid as in B	29·4 c.c.

I next endeavoured to ascertain whether the presence of an alkali (potash) or of albumen would modify the power of carbolic acid to restrain fermentation. It was determined that the presence of potash did not in the least degree interfere with the property of carbolic acid; whilst albumen exercised a very slight effect in restraining the action.

Mr. Crookes, in his Report to the Cattle Plague Commissioners related an experiment which tended to show—(1) that the action of carbolic acid in restraining fermentation was directed upon the *yeast;* (2) that the power of yeast to induce fermentation was wholly destroyed by feeble solutions of carbolic acid. He washed yeast with a 1 per cent aqueous solution of carbolic acid, and then washed away with water, as far as possible, the carbolic acid. The experiment, several times repeated, always showed that the power of exciting fermentation was wholly destroyed. The conclusion, however, has been contested by Pettenkofer, who says that though carbolic acid preserves ferment cells in an inert state, yet when the volatile acid has become dissipated these resume their activity. To obtain evidence on this point, I repeated the experiment in a different manner.

Having ascertained that 40 minims of a 5 per cent solution of carbolic acid was the minimum which would wholly arrest the fermentation when a drachm of yeast was added to solution of 25 grains of sugar, I prepared two precisely similar admixtures of yeast (1 drachm) and carbolic acid (40 minims of 5 per cent solution). One admixture I placed in a bottle loosely corked, the other in an open vessel standing in a water bath; temperature about 100° F. After the lapse of 12 hours, when it was reasonable to suppose that in the second case some of the carbolic acid had become volatilised, I poured the mixture upon a flat porcelain plate, washed it with water, and subjected it for 10 minutes to a strong current of air from bellows. The washing was occasionally repeated. The solution of sugar was then added to each of the yeast-admixtures, and both were placed in a water-bath at 100°. In neither case was there the least

fermentation. Inasmuch as the minimum quantity of carbolic acid which would under parallel circumstances restrain the fermentation was employed; and as it is reasonable to suppose that if the power of carbolic acid were evanescent *some* evidence of fermentation would have been given, it is fair, I think, to conclude that in this case the agent had rendered the yeast wholly and permanently inert. Though the solutions were kept many days, neither showed the least tendency to fermentation, though yeast from the same sample, uninfluenced by carbolic acid, readily gave rise to rapid fermentation. From these data I think it is fair to draw certain conclusions. First, it is seen that carbolic acid manifests a power of restraining saccharine fermentation, though in a less degree than has been asserted. Its power in this direction is much feebler than that of perchloride of mercury or sulphuric acid. Its action is modified by the bodies with which it is in relation. Alcohol and glycerine notably, and each in about the same ratio, impair this power; and olive oil exerts the same restraining influence in a much more marked degree. The presence of an alkali (potash) does not interfere with this property of carbolic acid, nor does its potassic salt possess (*pro tanto* the carbolic acid it contains) inferior power to carbolic acid itself. As regards, however, its more stable combination, as, for instance, sulpho-carbolate of soda, this direct power of restraining fermentation is diminished in a remarkable degree.

Without, as yet, hazarding any hypothesis as to the nature of fermentation, our data show that the yeast is the element which is acted upon, and there is no sign that this is *chemically* altered. The action upon the yeast would appear to be not temporary, but permanent.

Action on Putrefactive Decomposition.—Abundant experimentation has proved that carbolic acid prevents the putrefaction of organic substances.

A piece of meat soaked in a 1 per cent solution of carbolic acid for one hour entirely resists putrefaction. Gut, skin, &c., in like manner resist decomposition. Animal size and

glue in solution mixed with small quantities of carbolic acid are perfectly preserved in hot weather. Albumen precipitated by carbolic acid does not putrefy. A perfectly fresh egg placed in a sealed bottle, whose interior is coated with a thin lining of carbolic acid, may be preserved perfectly fresh for two months, although the bottle contain plenty of air; nearly the whole of the albuminous material is unchanged by the carbolic acid. Meat treated in like manner may be preserved untainted. A sparrow, observed by Lemaire, presented at the end of a month no signs of decomposition, its feathers being as firmly implanted as just after death. Putrefactive decomposition has also been prevented in the cases of fœcal matters and of blood. As well as preventing decomposition in cases in which the process has not yet commenced, it has also been proved that carbolic acid can arrest putrefaction when once it has set in. Thus meat was hung in air till the odour of putrefaction was strong. It was divided in two pieces; one was soaked in a 1 per cent solution of carbolic acid; the other in a solution of chloride of lime. In a few weeks that soaked in chloride of lime solution was very offensive, whilst the other presented no bad odour. When vessels were lined with carbolic acid, if by chance air were introduced so that volatilisation of the agent could take place, putrefaction commenced; when, however, the substance experimented upon was soaked in carbolic acid solution no putrefaction took place.

Action on Living Beings.—A. *Vegetable Organisms.*—A small proportion of carbolic acid prevents the germination of the spores of the yeast plant, and at once stops the growth of the plant at any phase of its subsequent development.

Mould and mildew are rapidly destroyed by carbolic acid. Spores do not vegetate on organic matters containing 0·01 per cent of carbolic acid. If a quantity of mould be taken from a vegetable syrup and placed upon a fresh syrup containing 0·01 per cent of carbolic acid the mould dies;

whilst on a syrup not containing carbolic acid it grows and fructifies as usual.

A solution of 1 per cent of carbolic acid destroys the germinating power of the following seeds:—Lentils, kidney-beans, barley, oats. It is necessary that the seeds be steeped in the solution a sufficient time that all the constituent liquids become impregnated with it.

Seeds do not germinate if the water necessary to their vegetation contain from 0·01 to 0·02 per cent of carbolic acid. If, however, seeds steeped in a solution of this strength be carefully washed and then placed under circumstances favourable to their germination, they will grow, but their vegetation will be 24 hours later than seeds not so treated.

Shrubs and Trees.—An application of strong carbolic acid to the roots speedily kills shrubs and trees; if applied to the flowers, leaves, and fruits, these die. If plants be watered with a solution of 5 per cent, a large number of flowers wither, but the leaves seem unaffected.

B. *Animal Organisms.*—An infinitesimal quantity of carbolic acid instantly kills *Bacteria, Vibrios, Spirilla, Amœbæ, Monads, Euglenıæ, Paramecıæ, Rotiferæ, and Vorticellæ.*

Ascarides die in a solution containing 0·5 per cent. Ova of ants, earwigs, and butterflies die in a like solution.

Lumbrici, as well as caterpillars, beetles, crickets, fleas, moths, and gnats, are killed by the *vapour* of carbolic acid. Insects have an intense aversion to it. M. Lucien Biard, of Mexico, says that when he is threatend with an invasion by an army of the large ants which infest the country, he sprinkles carbolic acid in front of the door of his house, with the effect of keeping away all the intruders.

Fish, frogs, and leeches die rapidly after immersion in a 5 per cent solution of carbolic acid.

It has a most powerful toxic action upon birds. Two or three drops applied under the wing of a sparrow cause first convulsions and then death.

Comparative Toxic Action.—Observations have been made with the view of testing the destructive power of

carbolic acid on minute organisms as compared with that of several other substances.* The minute organisms chosen for experiment were *spermatozoa* or *animalculæ.*

The Table (p. 27) shows the relative toxic power of the agents employed, the strongest being placed first. The organisms are arranged in the order of their sensitiveness to the poisonous agencies.

CHAPTER V.

ENQUIRY AS TO THE MODE OF ACTION OF CARBOLIC ACID IN ARRESTING FERMENTATION AND PUTREFACTION.

It must be acknowledged that carbolic acid has a great power in arresting and preventing both fermentation and putrefaction. The multitude of observations which have been made, the experience of almost every day, leave no room for doubt on this point. An answer to the question, what is the *rationale* of the action of carbolic acid in this respect ? is not easy. It may be well first to ascertain how carbolic acid does *not* act. In the first place, accumulated observations show that it does not exert any appreciable influence on oxidation. Oxidation of potassium, sodium, iron, copper, lead, manganese, phosphorus, has been observed to take place as readily in aërial or aqueous atmospheres impregnated with carbolic acid as in cases when the latter is entirely absent. The deoxidation of the atmosphere by pyrogallic acid or by the salts of iron, takes place as readily in the presence of carbolic acid as otherwise. From these premisses, therefore, it can be concluded that

* "On the Relative Powers of Various Substances in the Destruction of Microscopic Organisms," by John Dougall, M.B., C.M. Glasg.—"Lancet," Aug. 6, 1870.

Table showing the quantity of various substances in aqueous solution required to kill, in a given time, Spermatozoa, Infusoria, and Entomostraca.

Substance.	Spermatozoa.	Infusoria.	Entomostraca.	Average.	Remarks.
Hydrochlorate of strychnia	1-30000	1-450	1-8000	1-12816·6	The movements of the infusoria greatly increased at first.
Hydrochlorate of arsenic	1-18000	1-8000	1-2000	1-9333·3	
Nitric acid	1-18000	1-1500	1-300	1-6600	
Hydrochloric acid	1-15000	1-2000	1-300	1-5766·6	
Sulphuric acid	1-15000	1-1500	1-500	1-5666·6	
Alcohol	1-12500	1-750	1-2000	1-5083·3	Infus. when dying make small circles.
Bichloride of mercury	1-7000	1-6000	1-1500	1-4833·3	An entomostraca lived for 15 minutes in 1-2000, and was removed quite lively.
Nitrate of silver	1-6500	1-6000	1-2000	1-4833·3	
Acetic acid (*fort.*)	1-10000	1-500	1-50	1-3516·6	
Oxalic acid	1-7500	1-1500	1-1500	1-3500	
Chloride of zinc	1-7500	1-600	1-500	1-2866·6	
Picric acid	1-3700	1-450	1-2000	1-2050	
Tartrate of antimony	1-4000	1-450	1-500	1-1650	Infusoria when dying make short and sudden darts.
Hydrocyanic acid	1-5000	1-250	1-500	1-1583·3	
Carbolic acid	1-1000	1-750	1-1500	1-1083·3	
Camphor	1-2500	1-400	1-250	1-1050	
Tincture of iodine	1-500	1-400	1-500	1-466·6	Entomostraca struggle violently from the time they are put in the solution.
Solution of chloride of lime	1-500	1-300	1-250	1-350	
Common salt	1-10	1-50	1-100	1-53·3	Spermatozoa are rendered very lively by weaker solutions of common salt.
	Average. 1-7079·47 Time 15 min.	Average. 1-1676·3 Time 2 m.	Average. 1-1165·79 Time 15 m.		

carbolic acid does not manifest its effects in virtue of any power either of promoting or of impeding oxygenation. Moreover, it can be at once seen that the amount of available oxygen in the small proportion of carbolic acid employed must be wholly insufficient to alter the chemical constitution of the bulk of yeast. A reference to the table will show that the chemical constitution of a body is no guide to its power of arresting fermentation. I have found that, though 1-30th grain of perchloride of mercury will wholly arrest fermentation of a solution of 25 grains of sugar and a drachm of yeast, half a grain of chloride of calcium or of permanganate of potash is incapable of arresting it. Again, the carbolic acid which is recoverable from a fermenting or decomposing solution to which it has been added, is found to be unchanged in its chemical characters.

It has been shown, however, that carbolic acid has the faculty of coagulating albumen. Is it on account of this faculty that it prevents fermentation and putrefaction? On this point a comparative experiment throws some light. Let a solution of the albumen of egg be precipitated in one case by heat or by an ordinary chemical reagent, and in the other by a solution of carbolic acid, and let the resultant precipitate be kept a considerable time in contact with the air. It will be observed that, whereas in the one case the albumen will become decomposed in the ordinary manner, that precipitated by the carbolic acid entirely resists putrefactive change. It is, therefore, obvious that carbolic acid has an action over and above its action as a mere precipitant of albumen.

Moreover, there is no doubt that the coagulating power of carbolic acid upon albumen has been over-estimated. Albuminous solutions, in which carbolic acid is present in quantity too feeble to cause any coagulation, nevertheless resist decomposition ; and M. Lemaire has shown that an action of carbolic acid upon the merest fraction of the albuminous constituents of eggs and of raw flesh will arrest putrefaction.

So far we cannot arrive at any hypothesis to account for

the peculiar properties of carbolic acid. We can only conclude that it does not operate in any way obviously chemical. In searching for another explanation, we are led to the series of facts which place beyond a doubt the conclusion that carbolic acid has a manifest effect upon vitality—that it has the power of killing in feeble doses, and in a marked manner the lower manifestations of animal and vegetable life.

It is absolutely proved that in cases of the lower vegetable organisms (as mould and mildew), a very small quantity of carbolic acid absolutely kills the germs. In some of the higher manifestations of vegetable life—*e.g.*, grain and seeds, it is shown that carbolic acid retards growth and checks development only whilst it is itself present. There is not an actual death of the germ, but its vitality is held in abeyance. It would seem, therefore, that carbolic acid can be a poison in varying degrees to vegetable organisms. In what precise manner it compasses the inactivity in the one case and the death in the other, cannot be actually demonstrated. We have shown that inorganic chemical processes are uninfluenced by the agent. We find, moreover, that the oxygen, the food, and the carbonic acid, the excretion, of plants are uninfluenced; the conversion of starch into dextrine and dextrine into glucose is not affected. We cannot admit any metaphysical power in carbolic acid to seek out and destroy the principle of vitality; but we can conceive that by some physico-chemical actions upon the organic constituents of the plant, carbolic acid impedes or annuls those processes which are the necessary concomitants of perfect life.

When carbolic acid is added to a putrefying solution, it is observed that all the infusoria present in that solution instantly die, and the cessation of putrefactive change is coincident with their death. And when carbolic acid is added to a solution susceptible of putrefaction, but before the commencement of any putrefactive decomposition, no organisms are developed. The question then becomes an important one—Is there a causal relation between the

manifestation of living things and the occurrence and progress of putrefaction? And out of this grows a second question—Is it in virtue of its powers of suppressing vitality that carbolic acid manifests its faculty as an antiseptic?

The table already quoted as showing the comparative toxic action of various substances upon low manifestations of vitality has been adduced as a *primâ facie* argument that it is not by this power that carbolic acid operates; for if so, its power as an antiseptic ought to exist *pari passu* with the degree of its toxic action. But, in the first place, to sustain this, it should be proved that the antiseptic or anti-fermentive power of carbolic acid is higher than the agents which precede it in poisonous quality. I find, on the other hand, that the mineral acids and the metallic salts considerably exceed carbolic acid in relative anti-fermentive power. In the second place, the kind of living matter to which the power of effecting transformations is affirmed or denied, should be defined with more clearness. The table itself shows how widely the various kinds of organisms experimented on differ in their power of resisting a high toxic influence. Mr. Dougall has excluded from his observations all vegetable organisms. Strychnia, which is so potent a poison to animal life, abundantly *encourages* vegetable development and *favours* fermentation. It is obvious, therefore, that any argument based upon the relative powers of various agents upon vitalised matter which would exclude observations on the living material pertaining to the vegetable world would be incomplete and useless.

Finding, therefore, in its chemical qualities and powers no legitimate explanation of its admitted antiseptic action, observing its toxic power upon animal and vegetable organisms—ascertaining, moreover, that its antiseptic and its toxic agencies in case of a putrefying or fermenting solution are coincident and correlatively manifest, we have a *primâ facie* case that carbolic acid may owe its powers as an antiseptic to its *poisonous* qualities.

For a proper solution of the question of the agency of carbolic acid in preventing the processes of fermentation

and putrefaction, it behoves us to endeavour to obtain a clear idea of the nature of these processes. And we shall find that the enquiries upon the mode of influence of carbolic acid and upon the theories of fermentation and putrefaction will throw light each upon the other.

CHAPTER VI.

THEORIES CONCERNING THE NATURE OF PUTREFACTION.

Putrefaction is well known to be the process which dead animal or vegetable matters undergo when subject to air and moisture. Progressive changes are observed to take place in the chemical constituents of the organic substances, and these all tend to the splitting up of the originally complex body into simpler and still simpler combinations, till ultimately are evolved products belonging to the inorganic world.

In the course of putrefaction, the following classes of changes are noted :—

1. *Physical.*—The substances undergoing change manifest heightened temperature.
2. *Chemical.*—New organic compounds are produced in the putrefying material and gases are evolved. These are chiefly the following :—Nitrogen; hydrogen; ammonia; sulphuretted, carburetted, and phosphuretted hydrogen; carbonic acid; carbonic oxide; acetic, butyric, and valerianic acids; various phosphorus and nitrogen bases.
3. *Vital.*—Animal and vegetable organisms appear, grow, and multiply. They invariably accompany the process of putrefaction.

It is concerning the *rôle* played by these last in the phenomena that there have been so much doubt and such grave dispute. Around them twine the great questions—

What is the first cause of putrefaction? Are the appearance and the growth of these living bodies the causes or the consequences of the chemical changes?

In the earliest ages philosophers began to speculate upon this subject. When the ancients saw dead organic matter become peopled with living animals they thought that there was a re-conversion of the dead into the living. The corruption of one body was the generation of another.* They saw no difficulty in believing that the living forms were merely re-adaptions of the elements of dead matter; for they believed that rats and serpents could spring ready-formed from the soil, and frogs and fish from the moist slime of rivers.†

> "Cætera diversis tellus animalia formis
> Sponte suâ peperit."—*Ovid.*

No advance was made in any knowledge of the subject till 1638, when Redi, of Florence, by the simple experiment of surrounding morsels of flesh about to putrefy with coverings of gauze, showed that the worms which were formerly supposed to arise from the elements of the flesh were really developed from eggs deposited by flies. Soon afterwards the powers of the microscope were invoked to throw a light upon this question, though at first it must be confessed that this light was uncertain and fantastic. In 1745 Needham made a laborious series of researches, which showed that, though the higher forms of animal life which had been supposed to arise from putrefying matter came from extraneous sources, nevertheless putrefaction was essentially accompanied by the production of myriads of animalculæ of low endowments. The experimental evidence of Needham was very soon after systematised by Buffon. The low forms of life were supposed to arise in and from the dead elements of matter; and this method of spontaneous generation was "not only the most frequent and the most general, but the most ancient—that is to say, the earliest and the most universal." But even with the same evidence

* "Corruptio unius est generatio alterius."

† Plutarch, Aristotle, Virgil, DiogenesLaertius.

before them philosophers were not agreed; for Bonnet held that all nature was filled with multitudes of germs of living things ready to develope under suitable conditions. Experimental evidence was not long wanting to turn the balance to the converse of that obtained by Needham. Spallanzani entered ardently into the controversy. Needham had employed a method of investigation destined to play a very important part in the future of the question; he heated putrescible materials in vessels whereto the re-entry of atmospheric air was as rigidly as possible prevented; if there had been pre-existent germs, he urged, these must have been destroyed by the high temperature; animalculæ were discovered—therefore these must have been generated from the organic material. Spallanzani urged that in Needham's experiment the temperature was insufficiently high to destroy the vital properties of the germs. To suppress all production of infusoria, he said, it was necessary to maintain a boiling temperature for three quarters of an hour. From the dispute between these savants a moral may be deduced pertinent to all the stages of the enquiry. Both men of earnest minds saw in the same phenomena a different lesson. What was a destruction of germs with one was an annihilation of "vegetative force" with the other. The increasing use of the microscope led to further discoveries bearing upon the question. Treviranus (1822) established the interesting fact, that the forms and kinds of animalculæ observed varied with and depended upon, in the case of decomposing vegetable macerations, the kinds of plants employed. This was claimed as important evidence by the supporters of the spontaneous generation theory, though they are equally subject to interpretation upon the opposing hypothesis. Little of positive evidence was now for a considerable time added on either side, though opinion seemed to incline to that expressed by Lamarck, who said, "Nature, by the aid of heat, light, electricity, and moisture, forms spontaneous or direct generations at the extremity of each kingdom of living beings, where are found the most simple of these bodies." Cabanis, Bory St. Vincent, Bremser, Ticdemann, I. Müller,

Dumas, Dujardin, Burdach, and others followed with the same expression of opinion. Chemistry was at this time making great advances. Gay-Lussac, examining the air contained in bottles wherein putrescible substances had been preserved without undergoing decomposition, found that it contained no oxygen; he therefore concluded that the presence of oxygen was the essential cause of putrefaction. This view was soon to be exploded, for not only was it found that putrefaction was in many instances prevented when oxygen had free access to putrescible solutions; but the accuracy of Gay-Lussac's experiments was attacked, and it was found that in similar experiments to his own the absence of oxygen was found not only to be not constant, but even not general.

In 1837 Schwann made a notable experiment, which showed that no organisms were present in a putrescible fluid which had been previously boiled and supplied with air which had been calcined by traversing a strongly heated tube. The same sterility was observed by Schultze, when the air, instead of traversing a heated tube, passed over strong sulphuric acid or caustic potash. Furthermore, the same result was obtained (in 1854 and 1859) by Schröder and Dusch, when the air supplied to the flask was neither heated nor chemically acted upon, but only allowed to pass through a stratum of cotton-wool, which acted as a filter. It has been stated that similar experiments to these have not been *always* attended by the same results; but it is to be recollected that in all cases parallel observations were made. There was a strong agreement in the evidence to the effect that in the case of infusions supplied with air calcined or filtered no organisms were observed, whereas in those supplied with air uncalcined or unfiltered these were abundant. Objectors to the mode of experimentation should be ready with an efficient explanation of these results.

The general teaching of these experiments was decidedly adverse to the spontaneous generation theory, which also received another check from the microscopic researches of Ehrenberg. These demonstrated a very large number of

microscopic animalculæ to be propagated by ova; and there was no pretence for saying that these arose spontaneously.

The question had thus been to a great degree narrowed when an important era occurred in its history, M. Pouchet, with deep research, and, it must be added, strong partisanship, taking up the investigation. He carefully examined the progressive development of living forms in putrefying solutions, and, though he agreed that the higher forms of infusoria multiplied in the ordinary manner of ovulation, he declared that the lowest forms of life originated spontaneously from the organic elements of the solution. He said that organisms could be found in organic solutions which had been boiled, and to which no germs could have possible access, as instead of atmospheric air, an artificial atmosphere or oxygen alone was admitted to the flask. The microscopic observations were confirmed by Mantegazza, who patiently studied the appearances in decomposing solutions with eye strained at the microscope for 16 hours continuously. The opinions of M. Pouchet were strongly contested at the French Academy of Sciences by Milne Edwards, De Quatrefages, Claude Bernard, and others. Van Beneden, Jobard, and Gaultier de Claubry especially maintained that the vital resistance of germs was far more considerable than had been supposed; and De Quatrefages introduced a very important phase into the controversy by stating that he had found in the examination of atmospheric air "little spherical or ovoid bodies well-known to all microscopists, which gave rise involuntarily to the idea of an ovum of extreme minuteness."

In 1860 M. Pasteur took up the question, and by a series of careful and laborious experiments greatly advanced the subject in scientific accuracy, as must be conceded even by those who differ from him in his conclusions. He introduced an ingenious method of microscopically examining the bodies contained in ordinary atmospheric air. Filtering the air through a quantity of gun-cotton, he dissolved the latter in ether, and thus obtained in a small space a number of bodies whose appearance announced them to be organised. The

fact could not be contested. Pouchet himself, with his collaborators, Joly and Musset, agreed that the air did contain organised bodies, ova and microzoa; only they urged that these existed in wholly insufficient number to justify the conclusion that they were the sources of the myriads of living forms which people a putrefying solution. But the evidence adduced by Pasteur was far from being confined to that afforded by the microscopic examination of air. He repeated Schwann's experiments on the influence of calcination of air in preventing the appearance of organisms in putrescible solutions previously boiled, especially with a view to ascertain the causes of discrepancy in various observations. He concluded that the discrepancy depended upon the method of experimentation, that germs could enter the putrescible solutions by media which could be little suspected, especially that the mercury under the surface of which the necks of the sealed flasks were broken in the process employed could be a potent vehicle for the entry of organised particles. Pasteur furthermore tried the experiment of sowing the particles obtained by filtering air through cotton-wool in putrescible fluids supplied only with calcined air, and disposed in such a manner that without such sowing there should be no appearance of living forms. The results were that organisms appeared in precisely the time necessary for the same productions when ordinary air is supplied to the putrescible fluid. Another cause for differences in experiments performed by identical methods was declared by Pasteur to be variation of locality. In some places the air was more fruitful than in others; especially its fertility diminished in proportion to the altitude from which it was obtained. By further researches Pasteur concluded that the different kinds of organisms met with in putrefying solutions differed widely in the conditions of their nutrition and their vitality. Some absorb oxygen and excrete carbonic acid; others the converse:* some die, while others thrive in acid fluids, and *vice versâ*. After Pasteur's communications to the Academy many others

* Comptes Rendus, 9 Mars, 1863. Etudes sur le Vin, 1866.

from different observers more or less directly bearing upon the subject were made, his views being strongly contested by MM. Pouchet, Joly, and Musset. Very little evidence only except that of opinion, was added. An interesting communication, however, was made in 1863* by M. Béchamp, who showed the influence of certain substances which acted as poisons to germs in arresting the phenomena of fermentations, and declared that the appearance of different species of fungoid organisms depended upon differences of soil. In 1865 M. Trécul announced to the Academy researches which appeared to favour the hypothesis of spontaneous generation. He observed within the vegetable cells of *Ficus*, *Euphorbia*, the *Apocynaceæ*, &c., granules and starch corpuscles, which during putrefaction became changed into spores, germinated and ramified in the intercellular substance. In 1863 Lemaire,† though supporting the germ theory advocated by Pasteur, objected to the view that *special* ferments were required to produce the different kinds of putrefaction and fermentation. The general function, he said, of minute organisms is to reduce organic substances to a simpler state admitting of new combinations, and thus to prevent accumulations of unchanging matter. The presence of one organism or another in a putrefying solution is a non-essential part of the question; by changing the medium in which they exist, one can change the order of their development. The argument that organisms may appear in putrescible solutions exposed to a very high temperature is met by facts declaring the great powers of resistance possessed by certain low forms of life to these influences; and though a vegetable spore may be apparently destroyed, portions of its *débris* may yet possess vitality, just as a bud or a leaf can reproduce a vegetable, or a portion of a zoophyte become a perfect organism. M. Lemaire, in his work on the subject, 1863—1865, adduces the action of carbolic acid as a powerful argument in favour of the germ theory. The agent does not prevent the combination of any

* Comptes Rendus, 1863, p. 958.

† Moniteur Scientifique du Docteur Quesneville, November 1st, 1863.

substance with oxygen, so far as experimental evidence can declare; yet it prevents in a marked manner that oxidation which accompanies putrefaction. Why is this? The agent neither produces nor prevents any demonstrable chemical change, yet in its presence all the chemical changes which are the essential concomitants of putrefaction cease. It is shown that it is a powerful poison to low forms of life; it is shown, moreover, that when such low organisms cease to live, the whole of the phenomena of putrefaction are arrested.

Important evidence has since been added by investigations but little known in this country, those of Hallier of Jena. He brings forward very strong evidence to show that a single germ will develope into a variety of organisms according to the conditions in which it is placed. He traces the process from a sporule of mildew, which falls into an aqueous medium; the sporule is not to be looked upon (as it has been considered before) as a unity and the seed of a single plant. It is a collection of extremely minute particles aggregated together, which in the watery medium become separated, divide with great rapidity, grow, and become aggregated in little chains of *leptothrix*. Their future history depends on the nature of the fluid in which they are and upon the conditions to which they are subject. On the surface of some putrescible matter exposed to air they develope to mildew; in saccharine fluids, in wine, in milk, in oil, &c., they become the special ferments of these substances respectively. Fluids whose putrefaction is accompanied by the appearance of vibrios and bacteria are always alkaline; those connected with the appearance of mildew formations are acid. Vibrios are a distinct species not essentially connected with the putrefactive process. Chemical agents are poisons to these low organisms in varying degrees. Alcohol kills them, but acetic acid permits growth; the stronger mineral acids are fatal, but solutions of their salts frequently allow vegetation to take place in their presence.

Altogether, the researches of Hallier strongly support the germ theory. Very recently important evidence on the

subject has been added. Professor Tyndall, by a very ingenious method, showed that the ordinary respired air was charged with organic matter.* This could be rendered evident to any one by the electric light, the course of the beam from which is marked by the illumination of the suspended particles. It is not easy, Dr. Tyndall showed, to rid the air of these particles; they can pass through tubes containing strong chemical agents; they exist in air which has bubbled through a strong solution of caustic potash. They can be burnt in the flame of a spirit-lamp, and the smoke from their combustion can be observed—hence they must be organic. They cannot pass through the interstices of a plug of cotton-wool: this effectually filters the air from them. Air expired from the lungs is free from them—the pulmonary structure, like cotton-wool, acts as an efficient filter. Of course this evidence, which shows the organic character of the particles suspended in the atmosphere, in no way proves that they are organised. The question of the vitality of any of the forms must depend on collateral evidence. Professor Tyndall considered that these observations lent support to the germ theory, but he was opposed by Dr. Bastian, who warmly espoused the opposite cause. Dr. Bastian's elaborate researches, contained in "Nature,"† are intended chiefly to show that organisms can be produced under conditions which vitally-endowed matter could not be expected to support. Putrescible fluids exposed to temperatures varying from 146° C. to 153° C. for four hours, all air being rigidly excluded from the flasks containing them, nevertheless gave evidence of organisation, although there

* Lecture at Royal Institution and in Fraser's Magazine.

† See Germinal Matter and the Contact Theory. By JAMES MORRIS, M.D. Lond. Churchill, 1867. Dr. Morris almost forestalled Dr. Tyndall's method of demonstration. After showing that air floats minute masses of organic matter, he says:—"Sneeze into a sunbeam penetrating a dark room, and you will see myriads of such particles all containing organic matter, as small as the globules of mist or cloud. . . . . It is the sensible absence of such particles which makes us breathe with so much zest the air of the mountain or the sea."—P. 18.

‡ June 30, July 7, July 14, 1870.

was observed complete disorganisation of ordinary fungus-spores under like conditions. Moreover, organisms were observed in saline solutions maintained *in vacuo*, and germinal particles were even seen in the centre of crystals. Dr. Bastian sums up the following as the objects which he has attempted to show :—

"1. That there is a strong *à priori* probability in favour of the possibility of the occurrence of the heterogeneous evolution of living things, and that the most reliable scientific data which we possess do, in fact, fully entitle us to believe in this as a possibility.

"2. That microscopical investigation, whilst it teaches us as much concerning the mode of origin of crystals, enables us to watch all the steps of various processes of heterogeneous evolution of slightly higher organisms, such as may be seen taking place in a pellicle or a fluid containing organic matter in solution.

"3. That the kinds of organisms which have been shown to be destroyed by a temperature of 100° C. may be obtained in organic fluids, either acid or alkaline, which, whilst enclosed within hermetically sealed and airless flasks, had been submitted not only to such a temperature, but even to one varying between 146° and 153° C. for four hours.

"4. That a new and direct evolution of organisable compounds may, in all probability, be capable of arising, sometimes by isomeric transformation of the atomic constituents of a single saline substance, such as tartrate of ammonia, and sometimes by a re-arrangement of certain of the atomic constituents belonging to two or more saline substances existing together in solution. It is not only supposed that this may occur, but that even living things may subsequently be evolved therefrom, when the solutions have been exposed, as before, in airless and hermetically-sealed flasks, to a temperature of 146° to 153° C. for four hours."

Both the alleged facts and the reasonings of Dr. Bastian have been, however, strongly contested. Mr. Worthington Smith* considers that the majority of ovoid bodies de-

* Nature, Aug. 4, 1870.

scribed by Dr. Bastian as fungoid spores, are really nothing of the kind, but, if vegetable at all, are unicellular plants which multiply by fission; some of those figured, however, appear *bona fide* spores; but as these are provided with an elongation analogous to an umbilicus, it is more reasonable to suppose that they were generated from parents in the usual mode, than that nature producing them spontaneously should favour them with an umbilicus. It is much more likely that the spores obtained entrance into the infusions than that they were formed there. Professor Huxley, in his address to the British Medical Association, 1870,* subsequently to Dr. Bastian's investigations, gave the weight of his matured opinion to the converse of the doctrine upheld by Dr. Bastian. He considered that there were probabilities of error in the experiments; but even if they were trustworthy, he preferred the conclusion that living matter could resist extremes of temperature to the hypothesis of abiogenesis or spontaneous generation.

Dr. Bastian followed with another argumentative paper and some observations tending to show that in boiled infusions of meat, the air supplied to which was filtered through cotton-wool plugs, there were found, after periods of 42 hours and of 4 days, many tolerably active bacteria and a multitude of particles, some moving, some motionless.† Moreover, Dr. Bastian examined cases of provisions preserved in the usual way by exposure to a strong heat (said to be from boiling temperature to 200° C.) and hermetic closure, with the result of finding figure-of-8 bodies, leptothrix, bacteria, many of which moved pretty actively, and two or three portions of fungus filaments.‡

In reply to Dr. Bastian, Professor Huxley says there need be no surprise at such discoveries as have just been mentioned: the bacteria and fungus elements are such as are seen in any organic solution; they are not developed in it, but introduced with it—they are the preserved bodies of

* Nature, Sept. 15, 1870.

† *Ibid.*, Sept. 22, 1870, p. 413.

‡ *Ibid.*, Sept. 22, 1870, p. 433.

dead structures, the observed movements being not vital, but Brownian. Dr. Frankland repeated Dr. Bastian's heat-and-vacuum experiments with stringent precautions against the admission of atmospheric germs. A mixed solution of carbonate of ammonia and phosphate of soda was heated from 155° to 160° C. in a Papin's digester for four hours and then moved: the tubes containing it were plunged into sulphuric or carbolic acid. Examined five months after, particles were observed in form and characters resembling those described by Dr. Bastian. The *movement of the particles was obviously Brownian;* and many were "*evidently minute splinters of glass;*" there was not the slightest evidence of life in any of the particles.*

It has been said by some that this question should be judged wholly on experimental evidence, and that the mind of the observer should be unbiassed by the past. But I consider that it is an absolute necessity for the right understanding of it, that its various phases should be presented to the mind; only this should be done fairly and judicially. The question at issue can now be fairly stated, and the correlative issues can be understood.

There are two theories, then, with regard to putrefaction.

According to the one: Putrefaction is a chemical change which moist organic matter is prone to undergo under certain influences. It is a slow process of oxidation. Its *primum movens* is an albuminous body (the putrescible material itself), whose particles are in a condition of motion, which motion it is capable of communicating by catalysis to contiguous organic matter. The initial changes are chemical changes; these chemical changes place the organic matter in such conditions as to favour its transformation under ordinary physical forces into organisms possessing vitality. Hence these arise *de novo* from the dead material; their occurrence is non-essential to the process; either they are entirely adventitious,† or they are only intermediary

* Nature, Jan. 19, 1871.

† La presence de ces êtres microscopiques est entièrement fortuite et s'explique si l'ou songe que l'eau la plus pure n'en est jamais exempte, &c. GERHARDT.

means of transformation.* This view concerning putrefaction is held by the heterogenists, those who uphold the theory of spontaneous generation.

According to the opposing theory, putrefaction is a transformation of organic matter entirely effected by the influence of vitally-endowed organisms. The chemical changes in putrefaction are the sum of the products and the acts of living beings. The first cause is a multitude of minute particles of vitally-endowed matter derived from pre-existing living beings, contained in the air, permeating all substances which air itself permeates, wafted from place to place, finding in the putrescible fluid a suitable soil or pabulum in which in various forms to live, grow, and multiply. The universally-present living particles are essential to the process of putrefaction, and when they are destroyed putrefaction cannot take place. This is the view held by those who embrace the theory of Panspermatism, or, as it is briefly termed, the germ theory.

Having stated the issues in a way which I hope and believe to be fair on either side, I propose to examine the various kinds of evidence a little more closely.

CHAPTER VII.

EVIDENCE DERIVED FROM MICROSCOPICAL EXAMINATION OF PUTREFYING SOLUTIONS.

If a maceration of vegetable or animal matter be freshly made and a few drops be observed under the microscope, nothing can for some time be seen except lifeless organic *débris* and a few crystals. In a few hours the fluid can be observed by the eye to become slightly opalescent; and this opalescence is found to be due to a vast number of minute granules. Mantegazza, who made a continuous observation,

* Liebig's Chemistry of Agriculture, 4th ed., p. 348.

discovered them at the end of two hours. These organic particles are mobile, and are supposed by Pouchet, who calls them "molecules primaires mobiles" to indicate the point of transition from lifeless to organised matter; practically, however, the movements cannot be distinguished from those of inorganic matter known as Brownian movements. Soon the molecules rise and aggregate to the surface of the fluid, where they become motionless, and form a pellicle of a very finely-granular character, which gradually increases in density as more molecules arise to become incorporated with it. Thus is formed the "Proligerous pellicle" of Pouchet. During the formation of this pellicle a change has occurred in some of the granules of the fluid. Some have become more definitely spheroidal (monads); some of the monads have been supposed to become fused together, constituting short rod-like bodies (bacteria);* and there have appeared in a manner which is yet obscure, filiform bodies with a vibratile or serpentine movement (vibrios).† Of monads some are so minute as scarcely to be discovered by very high powers; the largest is but 1-30,000th inch in diameter. Some of the monads (*monas lens*) are provided with a fine prolongation in the form of a tail. Various species of bacteria have been described (*catenula, bacillus, termo,* &c.); they are generally in the form of short cylinders or parallelopipeds, and move rapidly in a straight line.

In the foregoing description I have chiefly followed Pouchet, Mantegazza, and Pennetier, but it must be acknowledged now that the inter-relations of these minute microscopic organisms were but very imperfectly known to them. The minutest monads cannot be distinguished from non-organised granules. As to the origin and nature of bacteria there has been great difference of opinion. Hughes Bennett, following Dumas, considers them to be formed by the fusion together of monads. Mantegazza, observing the fine molecules formed at the early stage of putrefaction, described little transparent motionless excrescences detached from the bodies of the granular mass, which he considered to be the *Bacterium termo* in the course of formation; three or

* Fig. 1. † Fig. 2.

four hours afterwards, the excrescences, having become free, are endowed with motion; they oscillate at first slowly, as if testing their own vitality,* and then swim rapidly in the fluid. According to Davaine, bacteria and vibrios belong to the same group, and all belong to the vegetable kingdom. They consist of mere filaments, either rigid and moving in a fluctuant manner (*Bacterium*), or flexible and having an undulating movement (*vibrio*), or spiral and rotatory (*spirillum*). But there are others besides, which are identical in their general forms with them but *motionless* (*Bacteridia*). All the varieties are closely allied to leptothrix. Many are so minute as to escape all methods of observation; minute as they are, vibrios vary in their physiological characters, in their relation with the fluid in which they float, and in their vital properties. Certain species live only in free oxygen; certain others live only when free oxygen is absent. Some vibrios may be completely dried without losing their vitality. Vibrios multiply by fission. In mobile liquids they multiply in greatest number at or near the surface; in thicker liquids, such as milk, they are equally distributed at all levels; in viscous or mucilaginous fluids they exist in disseminated groups. They may be distinguished from crystals and from filamentous bodies which resemble them by their resisting the action of liquor potassæ or sulphuric acid. Iodine colours them yellow and renders them more apparent. In the course of the putrefaction of the fluid in which they appear they die, vacuoles appear in their substance, and they themselves putrefy and disappear.

According to Pasteur vibrios constitute a large number of ferments (*e.g.* those of lactic and butyric fermentations and of right-polarising tartaric acid.) In putrefaction are concerned *Vibrio lineola, tremulans, subtilis, rugula, prolifer, and bacillus,* which are considered the special agents of the changes. In the course of the process *Bacterium termo* and its allies first appear and live only so long as any free oxygen remains in the fluid for them to absorb; then they either perish or rise to the surface, whence they obtain supplies of air. Then

* "Comme si elles s'essayaient à l'existence."—PENNETIER.

follows the appearance of those vibrios which do not require free oxygen for their vitality; these seize upon the combined oxygen of the putrescible material and transform the complex azotised into simpler combinations.

Vibrios and bacteria are met with in numberless situations besides their habitat in ordinary fermenting and putrefying matters. They are found within living bodies, in the tartar of the teeth, in the contents of the alimentary canal, in the urine even whilst still in the bladder, in purulent matters, in the blood, and in the morbid products of certain diseased conditions which we shall afterwards consider.*

Dr. Beale has observed bacteria in many of the fluids and structures of the animal body. He says, "In every part of the body of man and the higher animals, and probably from the earliest age and in all stages of health, vegetable germs do exist."† Dr. Beale has employed the highest powers of the microscope in investigating bacteria. He shows them to be mere masses of protoplasm; whether there is any investing membrane around them is doubtful. "It is more probable that each little particle of bioplasm is embedded in a soft and semi-fluid formed material which has been produced by it."‡ Dr. Beale figures these minute bacteria as multiplying by the detachment of off-shoots of their substance, but in some he draws quasinuclear aggregations within the bacterium itself, as if it showed a step towards propagation by ovulation.

According to Hallier, bacteria and certain monads are no distinct formations, but fragmentary chains of leptothrix or the germinal molecules, whence proceed under different conditions different fungoid organisms. He believes vibrios to be totally distinct organisms.

Concerning the influence of vibrios on the essential changes of putrefaction the evidence appears to me at present very inconclusive. Bacteria are found in myriads in

* DAVAINE, Article Bacterie, in Dictionnaire Encyclopédique des Sciences Medicales. Paris, 1868.

† Disease Germs, their Supposed Nature, p. 64.

‡ *Ibid.*, p. 34.

the most various localities, in situations where there is no reason whatever to suspect putrefactive or fermentive changes. It appears to me most important to dissociate in our minds mobile from motionless bacteria. I have seen myriads of bacteria and vibrios swimming in full activity of movement in fluids wherein all putrefaction was prevented by the presence of certain toxic agents in the air supplied to it. These are equally present at every depth in a fluid undergoing putrefaction, but it can be shown that the essential changes occur at the surface of fluids. It is here that the motionless elements are observed, and these can be shown to be the radicles whence fungoid organisms spring. The organisms figured by Hughes Bennett and other observers are in many instances obviously leptothrix.

We may next enquire into the nature of the "proligerous pellicle" of Pouchet, the "primordial mucous layer" of Burdach. This pellicle is, according to Pouchet, composed of the dead bodies of the forms just described which had enjoyed an ephemeral vitality. Its appearance varies according to the forms whereof it is composed, accordingly as there is a preponderance of monads, bacteria, or vibrios, and a different term is applied to the membrane in its different aspects—it is granular, fenestrated, pseudo-cellular, or mixed. To it was attributed an extraordinary power; it was considered the determining cause of all future organisation in the fluid employed; all the higher microzoa subsequently developed were said to be produced by the agency of the organisms, at first vitalised, afterwards motionless, which constituted this membrane. So, it was exactly analogous in its function to the ovary of the higher animals. "*Il est evident que c'est elle qui, à l'instar d'un ovaire improvisé, produit les animalcules.*"* Professor Hughes Bennett has endorsed this view in the following words :—

"What, then, it may be asked, is the origin of the infusoria or vegetable or animal organisms that we find in organic fluids during fermentation and putrefaction ? In answer to this question I answer, they originate in oleo-albuminous

* Hétérogénie, p. 353.

molecules which are formed in organic fluids, and which, floating to the surface, form the pellicle or proligerous membrane. These under the influence of varied conditions, as temperature, light, chemical exchanges, density, pressure, and composition of the atmospheric air and of the fluid, &c., the molecules by their coalesence produce the lower forms of animal and vegetable life."*

Before investigating this important proposition, it is right that we should know a little more of the physical characters of this membrane. In the first place, observers, as Cohn and Bastian, are not agreed with Pouchet that the monads and bacteria forming it are *dead*. Cohn showed that when its particles are set free from the edge of the pellicle, they resume motion. It is probable, therefore, that their movements are simply restrained by the jelly-like mucoid material in which they are embedded. Of what nature is this mucoid material? In some experiments of my own, wherein organisation was retarded by the presence of a volatile body in the air supplied to the putrescible material, the proligerous membrane is seen to be a transparent, structureless film. What, therefore, can be more probable than that it is simply the albumen of the putrescible material, more or less coagulated, which has risen to the surface?

Let us now consider the changes which occur in this pellicle as organisation advances in the putrescible fluid. The following are the appearances described, as ably summarised in the "British Medical Journal."†

"After a short time, the membrane, at first uniform and evenly granular, changes in aspect here and there, owing to a concentration of the granules at tolerably equal distances, into more densely aggregated spherical masses which at last become limited by a more or less clear border, suggestive of a resemblance to the zona pellucida of the egg of higher animals. This mass does constitute, in fact, according to Pouchet, the egg of the future ciliated infusorial animalcule.

* Popular Science Review, Jan. 1869, p. 65.

† August 7, 1869, p. 157.

The next change which takes place is, that the granules, which had been at first more densely aggregated towards the centre, then disseminate themselves uniformly through the ovum, whilst at the same time, the simple clear zone thickens into a distinct membrane.* A short time after this, differentiation still proceeding, the mass of enclosed granules gradually becomes converted into a real embryo,† which manifests its existence by slow movements—at first by simple oscillations in the mass of granules, and then by regular uniform movements of revolution of the whole contents within its enveloping membrane. The slightest shock, at this stage, immediately arrests the gyration. Then, after a time, a pale spot appears in a certain part amongst the granules, and soon the alternate contraction and dilation of this show that it is the rudiment of the future heart, or contractile space, of the infusorial animalcule. As other parts become differentiated, and the proper structure of the animal is attained, it begins to exhibit movements of quite a different kind—sudden and irregular, no longer checked, but rather increased, by slight shocks from without. In one of these sudden plunges the enveloping membrane is ruptured, and there enters into the world of waters a free swimming and perfectly formed infusorial animalcule—the offspring of Death, the embodiment of Life."‡

Dr. Bastian, whilst disposed to believe in the observations and generalisations of Pouchet, thus describes the "secondary organisation" in a vegetable infusion.

"In a pellicle which previously presented a uniform appearance, certain areas, altogether irregular in size and shape—though always presenting outlines bounded by curved lines—gradually make their appearance. These are, at first, distinguishable from the general ground-work of the pellicle only by their somewhat lighter aspect. On careful microscopical examination with high powers, it may be seen that the boundary of such an area—measuring it may be as much, or more than 1-300″ in diameter—is pretty sharply

* Figs. 6 and 7. † Fig. 8. ‡ Fig. 9.

defined from the surrounding unaltered granular stratum. The immediately contiguous granules of this are occasionally somewhat more tightly packed, though at other times no such change is observable. In either case the unaltered portion of the pellicle is quite different from the included lighter area, because in this an increase has, apparently, taken place in the amount of jelly-like material between the granules, and, as well, there is a certain alteration in the refractive index, and occasionally in the size of the granules (monads and bacteria) themselves. The next change observable is, that the included area shows lines crossing it here and there, which at first tend to map it out into certain larger divisions. These intersecting lines gradually increase in number, till at last the mass becomes divided into an aggregation of rounded or ovoid bodies each about 1-5000″ in diameter. As these subdivisions are taking place, the mass as a whole separates from the unaltered pellicle by which it is surrounded. Occasionally there is the most distinct interval, at a certain stage, between the parent pellicle and this differentiating mass, whose subdivisions also gradually separate from one another. These subdivisions now appear as independent unicellular organisms, bounded by a delicate membrane, and containing, perhaps, from four to eight of the altered monads and bacteria in their interior.*

Throughout the winter months, such areas of differentiation and such resulting unicellular organisms were frequently met with. The unicellular organisms seem during such weather to persist for a very long time in this condition, merely, perhaps, increasing somewhat in size, and most of them ultimately become disintegrated without undergoing further development. They were always seen in a completely motionless condition, and presented no trace of a cilium, so that they were altogether different from the creature known as *Monas lens*. In one solution of hay in which such organisms had been present for some time, after a few days of warmer weather, several of them were found to have become spherical, and to have undergone a considerable increase in size. Some of these were as much as

* Fig. 10.

1-2000″ in diameter, and on one occasion a stage in the actual transition of one of these unicellular organisms into an *Amœba* was seen with the most perfect distinctness. One-half of the organism was distinctly amœboid in character, whilst the other half was almost unchanged, containing large granules like those in the unaltered cells. As slow alteration in shape, of a slug-like character, took place in the anterior diaphanous protoplasmic portion, slow rolling movements occurred amongst the granules in the posterior cell-like portion, whose matrix seemed to have been rendered more fluid. I watched this organism for about half-an-hour, and then, wishing to examine other portions of the specimen of pellicle in which it had been contained, I moved the glass and was afterwards unable to find this particular specimen again. Unfortunately, I could discover no other *Amœbæ* or transition states.*

In other cases the areas of differentiation, commencing in a somewhat similar way, terminate in the production of spores of fungi, and I will now describe the mode of evolution of such spores, as I observed it taking place in portions of a pellicle having a brownish colour, from an old infusion of hay. The development of this brownish tinge in the earlier stages made it more easy to unravel the nature of the earlier changes. The areas which began to differentiate were generally not very large. They were at first quite colourless, and the granules were separated from one another by a notable amount of transparent jelly-like material. The granules themselves were mostly shaped like the figure 8, and each half was about 1-30,000″ in diameter. A later stage was seen, apparently, in other areas which had assumed a very faint brownish tinge, and which presented evidences that subdivision was taking place. As the process of subdivision progressed, so the brown tinge became gradually deeper. Ovoid masses were frequently seen about 1-2000″ or 1-1600″ in diameter, of a decidedly brown colour, with

* Professor Hartig has, however, described a similar mode of origin of *Amœbæ* from unicellular organisms, in his observations on the phytozoa of *Marchantiæ*."—See "Journal of the Microscopical Society," 1855, p. 51.

from 8 to 12 or more ovoid subdivisions within the common envelope. As multiplication advanced, the individual products lost all trace of their original granular condition. They became quite homogeneous and highly refractive masses of a brown colour, looking almost like large brown fat globules. At last, multiplication still proceeding, the distended, and always thin, cyst-like, general envelope becomes ruptured and disappears, leaving only an irregular mass of spherical or ovoidal bodies of various sizes. The individual segments, as soon as this process of multiplication has ceased, increase in size, and then gradually become less refractive and lighter in colour. A slight differentiation of their contents also again takes place, marked by the appearance of faint lines within, as they assume the appearance of ovoid bodies about 1-4000″ in diameter. Even when they have attained this stage of development, they may again undergo a process of division ; though generally, after a time, they give origin to ordinary mycelial filaments."*

From the foregoing data it has been supposed that a conclusion can be drawn favourable to those who embrace the theory of spontaneous generation. The view which they have been thought to establish is that the non-organised molecules contained in the solution become, under the influence of the physical forces with which they are in relation, endowed with the functions of life. Thus, there is an analogy between crystallisation and creation. Whereas in the one case, by the influence of external conditions upon invisible particles, there is an aggregation, according to certain laws which cannot be wholly explained, in definite forms and shapes, so on the other, by the union of particles under certain other external conditions, these become endowed with vitality.

Do microscopic observations warrant this conclusion as regards the lowest organisms observed, monads, vibrios, and bacteria ? It is said that the most profound microscopic investigations fail to discover any elements which can be

* Nature, June 30, 1870, p. 172. See Fig. 11.

pointed out as the germs whence spring these infinitely minute organisms. But it is impossible to declare of any infusion that it is destitute of organised particles which may be the parents of the living things with which the liquid subsequently teems. Professor Huxley states that he has tried over and over again to obtain a drop of a solution which should be optically pure, or free from solid particles, under a power of 1200 diameters, and he has always tried in vain. He believes that it is impossible to be sure that there is no germ of 1-40,000th of an inch in diameter in a given fluid.* Davaine says, "The primitive vibrios, germs if you like, are distributed irregularly at the surface and isolated from one another. Each of them becoming a centre of propagation, the groups spread, soon conjoin, and uniformly cover the surface. As soon as the pellicle which they constitute becomes appreciable to the eye their number is prodigious, and fissiparity multiplies them, so to speak, visibly."† "I feel sure," says Dr. Beale, "that anyone who patiently studies the simplest forms of life under the highest powers of the microscope will utterly reject the so-called *observations* which are adduced in support of the formation of 'spontaneous eggs' by the aggregation and coalescence of lifeless particles. In the ten-thousandth part of such a proliferous mass are living germs enough to produce by simple division in the course of a few hours countless multitudes of living forms."

But even granted that no specs of living material preexisting in the putrescible infusion were discoverable by any means, it would be a far too hasty conclusion if it were said that, therefore, bacteria, &c., were formed without germs. It is, at least, legitimate for us to conceive the existence of the germs of such organisms, although they may be far too minute for demonstration. The fully-formed fungus is many hundred times larger than the spore whence it has sprung; so it is legitimate enough to suppose that the germ

* Nature, Oct. 13, 1870, p. 473.

† Art. Bactérie, Dict. Encycloped. des Sciences Méd., p. 19.

‡ Disease Germs, their Supposed Nature, p. 56.

of the minutest monad, if such existed, would be utterly undiscoverable by the highest powers. It is impossible for us to judge this question according to evidence which is purely physical. No powers whatever can demonstrate when, or in what manner, a previously non-living molecule or collocation of molecules becomes vested with vitality. Professor Beale, who has examined living matter with the very highest powers yet adapted to the microscope, sees it to be only a pellucid, apparently structureless material, certainly not intrinsically differing in its appearance from matter which does not live. "There is in living matter nothing which can be called a mechanism, nothing in which structure can be discerned." I do not consider that the question of the nature of vitality is wholly pertinent to the enquiry. Vital force may be a force *per se*, or it may be a *marvellous correlation* of ordinary physical forces. It is equally impossible to explain how matter acquires and retains it, whether it be considered as one or as the other. But when matter has attained it, common experience shows it to be marvellously different from the physical forces with which we are ordinarily acquainted. The living morsel, besides manifesting motion and other phenomena of a physical kind, vastly differing, in amount at least, from that possessed by non-living matter, is capable of transforming the organic material with which it is in contact into living material akin to itself, and of perpetuating its power by multiplication or ovulation. It is obvious that the power which the molecule has thus acquired greatly transcends that which it possessed before, though there is no evidence of any mode of concentration of forces upon it, nor of any change in the forces themselves which are in relation with it. Under each theory there is a period which is of necessity a blank. Patient observers like Mantegazza may watch with strained eyes at the microscope for sixteen hours without intermission for the appearance of living forms; but the history of the molecules before they are visible must remain unwritten. To say that this gap could be bridged over no more satisfactorily than science has yet

accomplished, would be to state a finality which few would desire to accept; the history of minute investigations at once corrects the assertion, teeming as it does with discoveries of living forms which were formerly unseen, or which, if seen, were misunderstood. To apply to the possibly existent *primi-genetic* molecules the adjective "metaphysical," whilst denying it to the supposed non-organised force-acquiring molecules, is to my mind an abuse of terms. The latter view presents as many metaphysical difficulties as the former.

One of the most important branches into which the question divides is:—What is the relation of the proligerous pellicle to the organisms which are evolved? Is it essential or non-essential?

According to M. Coste, ciliated infusoria can appear in the fluid of an infusion long before the formation of the proligerous pellicle. He believed that a function had been ascribed to this which it did not possess. It has been urged in objection that the infusoria were introduced with the vegetable matter employed, and that they resumed their vital manifestations when they were moistened; but surely it is likely that the learned Professor of the College of France guarded himself against such an error as this.

Observations on the *Amœbæ* which are also found during putrefaction throw light upon the question. These differ from the organisms before described, as being recognisable by the highest powers merely as structureless matter, actively moving, rapidly changing in shape, reproducing by detachment of morsels of itself.* I am not aware of a particle of evidence which could refer the development of such a structureless mass of protoplasm to the influence of the proligerous pellicle.

Observers are not at all agreed as to the conditions of development in the pellicle, and the influence of its structure upon the development of organisms. It is a congeries of dead organisms (Pouchet), which have seemingly left in their molecules powers conducing to a higher vitality in the

* Fig. 12.

generation which succeeds them; or it is simply a mass of oleo-albuminous granules capable of being vivified by external influences (Bennett); or it is an aggregation of granular *living* matter capable of differentiation and further organisation (Bastian). Out of this chaos it is impossible to arrive at any definite conclusion as to the causal relations of the phenomena. A great deal of evidence shows that the lower forms are first formed, and afterwards organisms of higher and still higher endowment, though how this is accomplished the direct testimony of observation is powerless to declare. That a pellicle usually arises to the surface of a fluid in which organisms are developing is also proved, but that it is essential is a matter of doubt. Certainly its chemical and structural characters do not explain the power which has been claimed for it; the conclusion that it is a film of albuminous material common to putrescible solutions possessing no preternatural characteristics is at least as legitimate as the other hypothesis. That organisation takes place within it is favourable to either view, for it is undoubted that at the aërial surface of infusions, such organisation is to the greatest degree manifest. Possibly its influence is the physical influence of a protecting film over the new-born microzoa. At any rate the formative powers ascribed to it, without much more evidence as to its causal relations, must, I contend, be considered a pure assumption.

Taking the whole of the evidence afforded by the microscopic examination of a putrefying solution, I consider that the questions of the origin of vitality, and of the determining cause of the phenomena of putrefaction, must be considered undecided by the results of microscopic investigation. It is only by the concurrence of different kinds of evidence that the probabilities can be estimated.

CHAPTER VIII.

EVIDENCE DERIVED FROM EXAMINATION OF THE AIR.

It is obvious that this is a most important branch of the enquiry. If the germs of living things do not arise spontaneously, they must be wafted from place to place by some medium present wherever the phenomena are manifest. The atmospheric air intermingling with both fluids and solids could alone fulfil the indications.

The close relation between the presence of atmospheric air and the occurrence of the phenomena of putrefaction has been constantly admitted. It is a matter of common knowledge and common practice, that to expel the air from a putrescible substance is a powerful means of preserving it from putrefaction. The presence of air is one of the conditions insisted upon by the supporters of the theory of spontaneous generation as essential to the production of living forms. No other gas can be substituted for atmospheric air except oxygen.

Upon what element of the air does its influence upon the appearance of organised forms depend? The nitrogen may be at once dismissed, as direct experiment shows it to be fatal to organisms. The oxygen? Though this would seem probable from the direct experiments of Pouchet and others, who have found organisms developed in putrescible solutions, supplied alone with pure oxygen or artificial air, it is negatived by the facts, that though it be present in the atmosphere supplied to a putrescible solution, putrefaction may be at a stand-still; and that though all air may have been apparently rigidly excluded, the development of living forms may take place.* If the presence of oxygen be non-essential, how could we explain the positive results of Pouchet? Only by assuming that the germs of his living organisms entered by other media. We shall consider this exceptional condition hereafter.

* Bastian.

Schwann concluded from his experiments that it is not oxygen, at least the oxygen of the air, which occasions putrefaction, but *a principle* contained in ordinary air which heat can destroy. This same principle could also, according to Schroeder and Dusch, be arrested by the meshes of cotton-wool. It could be arrested by flexures made in a fine glass tube, which admitted air to a putrescible fluid, according to observations made by Pasteur and more lately repeated by Lister. It must be distinctly understood that these are not the invariable teachings of facts : there have been apparently contradictory results occasionally; but there is undoubted testimony that, in many instances wherein parallel experiments have been made with rigid accuracy, organisms have appeared, and putrefactions have taken place, where ordinary atmospheric air has been supplied to a putrescible fluid, while such have not taken place where means of interception, such as have been noted, have been collaterally practised. Why? The first step in the enquiry is the determination of the substances, besides the gaseous constituents which are present in atmospheric air. The suspended matters are proved to be—(1) A number of fine particles of inorganic matter. Chloride of sodium derived from the sea is proved by spectrum analysis to be present almost constantly; fine particles of the metals are present, especially in localities where are prosecuted trades wherein they are manipulated. (2) A quantity of organic *débris*. Starch-cells and fragments of vegetable tissue are common. Cotton and wool fibres are found in certain localities, besides many kindred dry organic substances. (3) Organic *débris* derived from the animal body is also abundantly found. Epithelium cells have been frequently observed in ill-ventilated rooms. Eiselt found pus cells in the air of an ophthalmic hospital. Organic matter, moreover, is given off from the lungs, for sulphuric acid is darkened, permanganate solution decolorised, and pure water rendered offensive by it.*

* PARKES, "Hygiene," p. 90.

(4) Lastly, organised bodies, spores of fungi, &c., have been seen by a host of observers.

The appearance of organised bodies in the ordinary respirable air was first satisfactorily established by Pasteur. Having drawn ordinary air through a filter of gun-cotton, he dissolved the latter in a mixture of alcohol and ether; then having allowed the solution to stand for a sufficient time, he examined the deposit by the microscope. Among the particles thus discovered were many whose form and structure announced them to be organised; they were spherical or oval, some translucid, some granulous; their dimensions were from an extreme minuteness to 1-100th to 1·5-100th of a millimetre. Some exactly resembled spores of mildew; but Pasteur adds, "as to affirming that one is a spore, much more the spore of a determinate species, and another is the ovum of this or that microzoon, that is, I consider, impossible."* Since this observation of Pasteur's, the microscopic examination of air has been made in many ways by different observers, and all have agreed as to the presence in it of sporules of cryptogams, and of bodies possessed of vitality. In water, through which the air of Manchester was drawn by Dr. Angus Smith, 250,000 fungoid spores as well as mycelium were found in a single drop by Mr. Dancer. In the air of sick rooms, hospitals, crowded halls, &c., many fungoid organisms have been noted by Trautman, Brittan and Swayne, Dundas Thomson, Rainey, Lund, Lemaire, and Ransome. More recently Dr. Maddox has carefully examined the particles derived from the atmosphere, collected by means of an apparatus devised by himself. He has found pollen grains, minute germs of fungi or protophytes, and excessively minute bodies, "molecules," "globules," &c.†

Another phase in the enquiry has been the examination of dust deposited from the air. Every microscopic observer knows how difficult it is to keep his specimens free from foreign particles deposited from the air. Pouchet, in the

* See Fig. 13.

† BEALE, Disease Germs, their Real Nature, p. 79.

examination of dust by the microscope in 1859 described *animal and vegetable particles* as constituents of dust. Mr. Samuelson was also one of the earliest to make like observations.

Dr. Percy found the dust of the British Museum to contain 50 per cent of inorganic matter. The latest investigations of this subject have been made by Mr. Tichborne, F.C.S.* The following were the results of analyses :—

Street dust in Dublin.

I.	Inorganic matter	68·9
	Organic matter	31·1
	(Containing nitrogen 1·07, carbon 57·5.)	——
		100·0
II.	Inorganic matter	54·8
	Organic matter	45·2
	(Containing nitrogen 2·1, carbon 57·5.)	——
		100·0

Dust of places of public concourse.

Organic matter varied from 32·1 to 53·2 } per 100 parts.
Inorganic matter varied from 67·9 to 46·8 }

Dust from Nelson's Pillar, 134 *feet in height.*

Organic matter	29·7
Inorganic matter	70·3
	100·0

Experiments were then instituted to determine how far the dust would operate as ferment, and *its remarkable power in this direction was conclusively shown.*

The fact of the presence of organised bodies in the air being to all intents and purposes uncontested, we have to consider their possible relations in the causation of the development of vital forms in putrescible solutions. On this point there is wide difference of opinion. M. Pasteur, with the Panspermatists, holds that they are the

* "Dust as a Ferment," Chemical News, October 21, 1870.

sources of all the organisation; M. Pouchet and the Heterogenists, that they are far too infrequent and insufficient to account for the phenomena. Pasteur calculated that "a little pellet of cotton-wool exposed for 24 hours to a current of air in the Rue d'Ulm during the summer after a succession of fine days, enclosed several thousand organised corpuscles for each litre of air drawn through it in a minute."* Pouchet, Joly, and Musset, on the other hand, hold that it is only exceptionally that the air contains a few ova of infusoria or spores of cryptogams. The question, "Are the organisms which have been observed and described sufficient to account for the multitudes of living forms which are met with in the course of putrefaction?" is of the first importance. If so, they ought to be observed upon or within the putrescible solution, and their mode of multiplication should be distinctly made out; for they ought at least to be as easily recognised in the one case as in the other. It is certain that this cannot by direct observation be established. As we have seen, the organisms or the organic molecules of a putrescible solution are at an early stage invisible. Moreover, it is objected that the mode in which the visible sporules propagate themselves does not account for the rapid peopling of a decomposing solution. Here it must be recollected—(1) that air pervades all matter which is in a fluid state, or in any condition in which there are spaces between the molecules; (2) that no infusion apt for the production of organisms is optically pure or free from the possibility of existence of protoplasmic molecules. It is probable that from a very few centres of bioplasm a solution could be soon peopled with living particles. Davaine calculated that a single bacteridium-particle would in the course of 24 hours become the parent of 4096 such particles; after 48 hours, 16,777,216; between the 60th and 62nd hour the numbers would reach from 1,000,000,000,000 to 71,000,000,000,000. That there are abundant sources for such starting-points of vitality is a matter of no doubt whatever. A calculation

* Annales de Chimie et de Physique, 1862, p. 32.

has been made that, if "each spore of one species only of one of the higher fungi germinated and reproduced its parent, the children would in the first generation, and in the course of a very few days, form a carpet all over the earth. As fungi abound everywhere in myriads, and the family is almost illimitable, the number of diffused germs is evidently beyond all calculation."*

Suppose, however, we concede that the starting-points of vitality in a putrefying solution are themselves invisible, there remains this dilemma: either the germs are invisible, or else the primigenetic molecules are self-formed in the fluid. We should then enquire if there is anything in analogical evidence which could tend to the conclusion that the germs of living things are so minute that the microscope cannot detect them. Dr. Beale, using the highest powers, figures extremely minute masses of germinal matter which develope into perfect fungi, yet which might elude very close investigation; and it is far from certain that these are but the indices of still more minute particles of living matter.† It is surely unfair to stay further investigation by asserting at once that because the germs cannot be demonstrated, therefore the enquiry is at an end and the question is judged. The heterogenists have constantly urged this: they say, "Show me a specimen of these creatures and I will admit them; otherwise I shall declare that they do not exist." The eye alone is not the test of the cause of phenomena. Would a philosoper assert that a man could safely enter a poisonous atmosphere because he could see nothing wrong with the highest aid to his visual powers? Would it be right to conclude, after the inoculation of vaccine virus into an animal, that no virus exists in its blood because none can be detected? Indirect observations have shown that the *organic* particles of atmospheric air may pass through channels which *à priori* consideration would lead us to think would intercept them.‡ Again, as M. Pasteur remarks, "I should

* WORTHINGTON G. SMITH, Nature, Aug. 4, 1870, p. 276.

† Fig. 14.

‡ TYNDALL.

observe, besides, that with a thickness of one centimetre, a plug of cotton-wool is far from arresting all the corpuscles of the air. If we place several plugs in a series, the second, the third, &c., absorb dust." It need, therefore, not be surprising that though a plug of cotton-wool might by arresting organised corpuscles arrest putrescence in one case, it might fail to do so in another.

Though, therefore, it may be urged that the microscopic evidence has narrowed the limits of the question; though it can be no longer held that those organised forms which are demonstrable by the microscope are the sole sources of all the myriad organisms which people a putrefying solution, it cannot exclude the probability that the germinal molecules whence spring these organisms are of extreme minuteness. But for the facts of their possible interception by physical media, I do not see any absolute difficulty in conceiving then of a tenuity almost equalling the particles which constitute the air itself. At any rate, the objection derived from the fact that they cannot for the most part be demonstrated is an inconclusive one. Nay, here I consider that the metaphysical difficulties are quite as great on the other side. It is as easy to conceive the existence of minute particles which cannot be demonstrated as it is to imagine—first, the acquirement by no known means of vital powers by non-living matter; secondly, the assemblage of these units, living or dead, under the influence of a proligerous pellicle or otherwise to constitute higher forms of organisation; thirdly, the possession by such living matter of powers of vital mutation and self-multiplication, which under the first hypothesis would be supererogatory.

But, granted that the existence of such minute masses of pre-existent living material is possible, it is undoubted that there are grave difficulties yet in the way. The first difficulty may be stated thus:—The spores or germs of definite fungi are themselves definite; they are not of infinite minuteness; these fungi nevertheless spring up when it is absolutely certain that their ordinary spores cannot be discovered. The second difficulty is this:—The organisms

found in putrescible solutions are of many varieties and species. There must be definite and distinct germs for each of them. You must, therefore, concede that the air contains multitudes of these, that every square inch of it is a magazine of innumerable varieties. The air would be then encumbered with germs.

These questions, which may be styled those of the specificity and plurality of germs, will be best treated after the subject of fermentation.

CHAPTER IX.

THE NATURE OF FERMENTATION.

The conditions of fermentation and of putrefaction are closely allied. The presence of a putrescible body is essential for the commencement of both; in both the development of organised forms occurs. The difference between the one and the other consists chiefly in the evolved products; when these are complex and numerous, and offensive to the smell, the process is termed putrefaction; when the products are uniform for each kind of matter employed and not malodorous, the change is termed fermentation.

The following are those which at the present day are generally admitted as the varieties of true fermentations:—(1) alcoholic; (2) lactic; (3) butyric; (4) aceto-butyric; (5) fatty (various forms); (6) succinic and aceto-succinic; (7) viscous; (8) tartaric; (9) acetic; (10) ammoniacal; (11) glycosic of tannin. Besides these, certain changes in organic bodies, wherein there appears to be a mere rearrangement of atoms without any observed development of living forms, have been classed as fermentations. These, which may be considered as catalyses, are—(1) dextrino-glycosic of amylaceous bodies; (2) glycosic of saccharoses; (3) glycosic of mannite and glycerine; (4) glycosic of

glycosides; (5) pectic; (6) glyceric of fatty bodies.* In all those mentioned as true fermentations the development of organisms is invariable; and the varieties are constant for each kind of fermentation. As in the case of putrefaction, opinions differ as to the nature and causes of the processes chiefly in relation to the part played by these living bodies. For the Heterogenists fermentation is a molecular change produced in a fluid containing organic matter by the influence of a putrescible body, the *mode* being the communication to the fluid of motion from the particles of the putrescible body. For the Panspermatists fermentation is a change induced upon organic fluids by minute organisms, the fluids standing to them in the relation of food or of soil.

The *conditions* of fermentation are pretty well established to be the following:—

(1). There must be a substance capable of undergoing fermentation, as the sugar which is capable of being resolved by the mere re-distribution of its elements into alcohol and carbonic acid. (2.) Since the phenomena are not immediate, there must be a lapse of an appreciable though a variable period, and the changes are not instantaneous but progressive. (3.) There must be certain conditions of temperature. (4.) The presence of water is indispensable. (5.) There must be the presence of a ferment (as the yeast in alcoholic fermentation), which may at the present be defined as "a nitrogenous body undergoing change." It is this last which is acknowledged to be the chief determinator, the *primum movens* of fermentation, and it is concerning this element that there has long existed a remarkable controversy.

The ancients knew that a ferment was a body which imparted to certain fluids a perturbation which resulted in a large increase in the bulk of the ferment itself, and an organic alteration of the fluid submitted to its influence.

In 1840 Liebig endeavoured to reduce the essentials

* GAUTIER, Etudes sur les Fermentations Proprement dites et les Fermentations Physiologiques et Pathologiques. Paris, 1869.

of the phenomena to a single expression, and enunciated that fermentation is communicated motion. A ferment is an organic body whose particles are undergoing changes; the product of these changes is motion: such motion is capable of communication by contact, and is communicated under favouring circumstances to a fermentescible body; from organic changes so induced result the phenomena of fermentation. It cannot be said, however, that this expression is a new hypothesis. It had been taught ages before. Dr. Mead, in 1702, wrote, "What is thrown out of liquors in a ferment is capable of inducing the like motion in another liquor of the same kind."* Liebig, however, made a great step in advance, by showing concerning the generic character of ferments that they were albuminous bodies—that they were nitrogenous. The hypothesis, however, left unexplained the *mode* in which motion was communicated from the ferment to the fermentescible body. The power enjoyed by the particle of ferment is unique; it produces effects which matter under other circumstances does not possess.

The advancing use of the microscope and the accumulated results of observers threw great light upon the mysteries of the process.

In 1680 Leewenhoeck found yeast to consist of spherical or ovoid bodies. In 1835-37 Cagniard de Latour described it as "a mass of globules susceptible of reproduction by budding," and considered it very probable that, by some effect of their vegetation they disengaged carbonic acid from the saccharine liquid, converting it into a spirituous solution. Desmazières expressed a like opinion, and observations confirming the organised nature of yeast followed from Turpin, Schwann, Mitscherlich, and other investigators. In 1843 Helmholtz showed that the faculty of exciting fermentation in a saccharine solution did not reside in the *fluid* portion of the ferment, for when he separated a putrefying or fermenting liquid from one which was capable of

* A Mechanical Account of Poisons, by RICHARD MEAD, M.D. (London, 1702), p. 81. See also pp. 13—15.

putrescence or fermentation though not undergoing the process, the latter, though it became impregnated with the products of the fermentation, &c., of the former, did not itself ferment, nor manifest the living organisms of fermentation. It was obvious, therefore, that the excitors of fermentation, &c., could not pass through membranes.

Dumas acknowledged that fermentations are always phenomena of the same order as those which characterise the regular accomplishments of acts of vitality. In every fermentation, he says, there appears as a principal agent a nitrogenous organised material which seems to live and develope.

Thus, it is acknowledged on all hands that living vegetable organisms play an important *rôle* in the phenomena of fermentation. Universally present, they are, if not the determining agents, at any rate intermediate agents, in the conversion of the complex organic body, sugar, ($C_6H_{12}O_6$), into its simpler constituents, alcohol, (C_2H_6O), and carbonic acid, (CO_2).

The question next occurring is—Are ferments "*vi et naturâ*" living beings? If not, what is their precise function? According to the authoritative enunciation of one of the latest writers, a ferment is a body which "places liquids in special conditions favourable to the development of organisms." The word ferment is applied to all decomposable bodies whose contact can produce new chemical combinations, and albuminous bodies occupy the first rank. The chemical reactions occupy the first place; the vital manifestations are secondary. "The forces put in action by the chemical reactions determine organisation and life in the midst (*sein*) of liquids in fermentation."* The memorable "Mémoire sur la Fermentation Alcoolique," which appeared in the "Annales de Chimie et de Physique," 1860, marked a new era in the history of fermentations. Examining the chemical details of fermentation with the skill which his well-known ability as a chemist qualified

* PENNETIER, Origine de la Vie, 2ième ed., p. 256.

him for, Pasteur nevertheless concluded that the determining cause of fermentation was not a chemical but a vital act. He recognised as the essential parts of yeast—(1) the yeast-cells; (2) the albuminous fluid, which is the necessary, suitable aliment for the cells. The transformation of sugar into carbolic acid and alcohol was strictly correlative with the phases of life of the yeast-cells. He said, "The chemical act of fermentation is essentially a phenomenon correlative with a vital act, commencing and ending with the latter. I believe that there never is alcoholic fermentation without there being simultaneously organisation, development, and multiplication of globules, or life progressive and continuous of globules already formed."

The great difficulty in the way of this explanation was, and is now, with many observers, the fact of the existence of *fermentations apparently spontaneous*. It is well known that without the addition of leaven certain saccharine solutions will present all the phenomena of fermentation with the development and growth of yeast-cells. In like manner, the other fermentations can occur with the production of the organisms common to each. The question, therefore, turns upon the origin of living forms, just as it did in the case of the phenomena of putrefaction.

In a second essay, entitled "Mémoire sur les Corpuscules Organisés qui existent dans l'Atmosphère, Examen de la Doctrine des Générations Spontanées," Pasteur addressed himself to the task of endeavouring to explain the difficulties and reconcile the apparent discrepancies. Having, as before stated, described the microscopic organisms found in atmospheric air, he pointed out that these might probably be carried into putrescible fluids without the greatest precautions being taken to ensure their absence: thus could be explained in many instances the discrepancies of different observers, and even the same observer: the mercury of the mercurial trough used in many experiments was declared on plausible evidence to be a potent vehicle for germs. Then M. Pasteur proceeded with the investigation by sowing the particles filtered from the air in organic liquids, making

parallel observations with the same organic liquids not so treated. The results were the appearance of productions of the same order in the fluids in which the particles had been sown as these are usually observed in the fluids when abandoned to ordinary air. He found that when a boiled putrescible fluid was supplied by air which traversed a fine glass tube bent at various angles, organisms did not develope therein, the cause being that the organised bodies which the air normally contains were arrested by the flexures of the tube. He summed up his conclusions so far in these words:—

"1. There are constantly in the air organised corpuscles, which cannot be distinguished from true germs of the organisms found in infusions.

"2. When one sows these corpuscles, and the amorphous *débris* which are associated with them, in liquids which have been boiled, and which would have remained intact in air previously heated if this sowing had not been practised, there are seen to appear in the liquids exactly the same living forms which they develope in free air."

He adduced evidence, moreover, to prove that the air of some localities is richer in germs than the air of others; notably that of high mountains is comparatively free from them. He then endeavoured to show that the germs could withstand temperatures higher than those which it was usually thought were fatal to them; that the spores of common mildew could resist a temperature of 120° centigrade. As regards the albuminous material, which had been considered as the determining cause of the phenomena, he adduced experiments to prove that its function was that of a food to the germs of fungi and infusoria, and it could be replaced by crystallisable matter, such as the salts of ammonia and the phosphates, without interference with the ordinary phenomena. Lastly, it was shown that the mode of nutrition of the lower forms of fungi differs from that of phanerogamous plants; they absorb not carbonic acid but oxygen; the former they exhale. These views were sternly contested by MM. Pouchet, Joly, Musset, and others. Their objections were chiefly—(1) that yeast-cells were formed in

fluids in a manner identical to that obtaining in the apparently spontaneous development of spores and ova in putrefying solutions. Each yeast-cell is considered a spore, which germinates and branches; the branches divide by septa, and ramify in the fluids; finally is produced a genuine fructification. In the liquid yeast the cells are separated by a glutinous material, which is thicker in the neighbourhood of each cell forming a zone around it. The agglutination by means of this viscid material of one cell to another gave rise to the commonly-received notion, that the cells were propagated by budding; (2) the chemical phenomena of fermentation occur prior to the appearance of organisms; (3) the fluid part of the yeast is capable when no yeast-cells are present in it of inducing fermentation; so, also, are other putrescible bodies, as urine, the venom of serpents, fragments of human brain, &c. . Lastly, fermentation could take place under circumstances of temperature which, according to analogy, are fatal to objects possessing life.

The foregoing views regarding the yeast-cell have, however, received contradiction from other observations. M. Trécul (Comptes Rendus, 1868, p. 137) insisted that it is propagated by budding and division. It was shown, moreover, that there was a distinct relation between the phases of growth of the cells and the occurrence of fermentation. Thus, the well-developed branching *Mycoderma* does not excite fermentation, whilst the young non-ramified mycoderms develope it energetically. Furthermore, the interesting observation was made that other fungoid spores than that peculiar to yeast could, in a manner precisely similar to the latter, induce fermentation. *Penicillium* cultivated upon lemon, gave rise to alcoholic fermentation with the production of yeast-globules, and, conversely, yeast-globules were found to produce *Penicillium* as well as *Mycoderma*. It is obvious that this observation of the mutability of species in fungoid organisms is of the highest importance. The apparent structural characters of the spores and the subsequent developments and fructification of *Mycoderma cerevisiæ* differ widely from those of *Penicillium*.

If they are thus mutually convertible it would annihilate the argument advanced against the existence of atmospheric germs on the score that to explain the different varieties of forms produced, we must concede the existence of an immense number of germs in the air of different kinds. This would tend to show, on the contrary, that the same germ under different conditions could assume the appearances and the functions of a different organism. According to Trécul yeast-cells variously cultivated can develope not only into *Penicillium glaucum*, but into *Aspergillus*, *Ascophora*, &c.* Conversely, *mucor*, &c., can develope yeast-cells. Duval ("Thèse de l'Ecole de Pharmacie de Paris," Avril, 1864) found that alcoholic fermentation was excited by the addition to a fermentescible mixture of a few particles of *palmella*. In the cellules of the plant itself spherules became evident, which eventually burst from their envelope and developed as ordinary cells of yeast. Portions of *Penicillium* also gave the same result. These observations, taken in conjunction with the more systematic ones of Prof. Hallier, cannot fail to afford very important evidence.

The work of M. Gautier gives a very good picture of the conditions of the question of fermentation, illustrated as it has been by the researches of Pasteur. A clear division has been made by Gautier of fermentations into two classes —one, in which cellular or vitalised elements are intimately concerned in the process (fermentations à ferments figurés); the other, in which no organised elements are concerned (fermentations à ferments non figurés).

It was urged by Berthelot that a certain number of the changes classed as fermentations could not be due to the presence of germs because the ferments which determine them are *soluble*. Such are the transformations of starch into dextrine and glucose, and albumen into peptone. Gautier, however, objects to this: he considers that they are rather diffused and suspended in their fluids than really soluble, for they can be entangled and precipitated from

* Comptes Rendus. Séance du 27 Juillet, 1868.

their media by collodion or phosphate of calcium. In most of the fermentations which take place independently of organisms, definite chemical agents can produce the same results as the special ferment itself. These ferments exist in almost all parts of plants and animals; they are of complex molecular constitution; in fact, they seem to be at the extreme limit dividing organic from organised material. The changes they effect are not profound; they do not cause violent disruption of the molecule they act upon and change its internal structure, but in general they induce in it an isomeric transformation, causing hydration or a re-arrangement of its molecules. The diastase of malt, which effects the transformation of starch into sugar, was isolated by Payen and Persoz. Mialbe discovered, however, in saliva a diastase having like properties. Other forms of diastase were shown to exist in pancreatic fluid, in the soluble portions of yeast, and in many of the juices of plants. Magendie and Berthelot found that any decomposing albumenoid substance could in some degree act as diastase. Cane sugar, as well as others of analogous constitution and termed saccharoses, under the influence of a definite quasi-soluble ferment isolated from the filtrate of yeast, becomes converted into grape sugar or analogous glucosides. Amygdaline, myrosine, and many other vegetable principles, under the influence of emulsine, a soluble ferment, become decomposed into glucose plus other compounds. Unripe fruits contain principles which, under the influence of a ferment, *pectase* (Frémy), become transformed into a soluble substance, pectine.

The ferments which, according to M. Gautier, produce the foregoing changes, are therefore organic, but not organised. Those which he describes as "ferments figurés" are all complete and independent organisms, endowed with life, having determinate form, and capable of reproduction. These ferments belong some to the animal, some to the vegetable, world. The ferment which changes sugar into alcohol is the *Torula cerevisiæ*, concerning which Pasteur's dictum was "Sugar never undergoes alcoholic fermentation without

living yeast-globules being present." Lactic ferment, according to Pasteur, consisted in short cells resembling yeast. Berthelot only recognised molecular granules. Butyric ferment was, according to Pasteur, a vibrio living only in the absence of air. Acetic ferment was described by Pasteur as ovate cells slightly constricted in the centre, aggregating in chains, and multiplying by fission: he termed it *Mycoderma aceti.* It is certain, however, that the power of transforming alcohol into acetic acid belongs to other substances besides these organisms. The ferment of ammoniacal fermentations was described by Jacquemart, H. A. Müller, Pasteur, and Van Tieghem: it is considered as a series of minute globules tending to aggregate in chains.

We will now turn to the latest teaching of Liebig on this subject. I think I am justified in the inference that in this country medical philosophers, at least, are accustomed to look upon this illustrious chemist as the veteran opponent of the germ theory. It will be seen, however, that this view is not tenable. Liebig does not reject the germ theory, but amalgamates it with his own motion theory: in this, however, his expressed views are not novel. In the series of researches on fermentation during 1855—1860, published by M. Berthelot, it was asserted that many organic substances (as dextrine, glucose, &c.) could give rise, though slowly, to alcohol without any development of yeast; thus, though yeast was acknowledged to be by far the most efficient ferment, its presence is not absolutely necessary. According to Berthelot, the living ferment does not effect transformations exclusively by its vital acts, but by these in conjunction with properties which it has in common with soluble ferments. The fermentescible matter taken up by the living ferment meets with other soluble ferments which induce the transformations called in their *ensemble* fermentation, just as in the body of a mammifer starch is converted into sugar by the soluble diastases and albumen into peptone by pepsin.

This appears to be almost precisely the view enunciated

by Liebig.* "From the chemical point of view, which I cannot abandon," says Liebig, "*vital activity* is a *state of motion*, and in this sense Pasteur's view is neither inconsistent with mine nor antagonistic thereto. There is, I believe, no difference of opinion as to the behaviour of yeast in beer-wort; so soon as perfect yeast-cells have been formed the decomposition of sugar commences, and at the same time the formation of yeast goes on incessantly, until all the sugar is decomposed." The breaking up of sugar is accompanied by a decomposition of the cell-contents, whereby a soluble nitrogenous substance is exudated into the surrounding fluid. "The significance of the plant organism in the phenomenon of fermentation appears to be clear, for it is only through its agency that an albuminate and sugar can be united into a peculiar compound in the liquid where the yeast-plant is developed, or, in other words, associated in that manner in which they can, as a constituent of the fungus, exercise an influence on sugar. When the fungus ceases to grow, the bond uniting the constituents of the cell-contents is dissolved, and it is the molecular motion acquired by the cell-contents which enables the yeast-cells to determine a dissolution of the sugar elements, or their separation and re-arrangement into other organic molecules." †

In acetic fermentation the *rôle* of the plant organism is only that of an oxidiser. It is beyond doubt that the vinegar plant is capable of causing the conversion of alcohol into acetic acid; but this is not the effect of a purely physiological process, the plant absorbing oxygen from the air becomes the agent of oxidation, and this property it shares with finely divided platinum as well as many organic substances.

From the foregoing data we can enunciate three theories as to the nature of fermentation. According to the first it is

* Annalen der Chimie und Pharmacie, 1870. Translated in Pharmaceutical Journal, July 23—30, August 6 and 13, 1870.

† Liebig, Translation in Pharmaceutical Journal, July 30, 1870, p. 84.

purely a chemical process, and the organisms met with are merely adventitious.

According to the second (Pasteur), it is purely a vital process, and the organisms observed are essential to it and correlative with it.

According to the third (Berthelot, Liebig), it is a physico-vital process, and the organisms, though for the most part essential, are not absolutely so, but are intermediary agents.

One source of error in the deductions which have been made has arisen from a misconception as to the histological characters of yeast. It has been supposed that because the filtered washings of yeast can excite fermentation, alcoholic fermentation cannot be due to the influence of living yeast-cells; but Dr. Beale has shown that the gemmules of yeast, each of them capable of independent existence, are many of them much less than 1-100,000th of an inch in diameter—in fact so minute that they would pass through the pores of the finest filter.*

Another source of difficulty has been the variety and the total dissimilarity of organisms which have been asserted by Pasteur and others to be the special agents of the various kinds of fermentation. Hitherto no bond of union had been shown to connect them.

The most elaborate investigation of recent date bearing upon this subject has been made by Professor Hallier of Jena.†

According to Hallier, the same germinal molecules develope according to the nature of the fermentescible substances in which they are deposited into the fungoid forms peculiar to each fermentation. The forms inducing putrefaction, fermentation, and mildew, are all varieties of one another. As they develope within fluids they are cellular formations (Hefe); when they grow upon the surface only do they present fructification (Schimmel). Hallier endorses Pasteur's view, that the germs of all are carried by the air.

* See Figs. 15 and 16.

† Gährungsercheinungen. Leipzic, 1867.

The most abundant source of germs appears to be *Penicillium crustaceum*,* whose spores are universally spread because it is more hardy, more fertile, developes at lower temperature, and grows and fructifies more rapidly than others of its kind. It will accomplish its growth, and will bear fruit in forty-eight hours. A so-called spore of *Penicillium* falling into watery fluid, bursts into a multitude of particles (schwärmer),† each of which may be the radicle of a living fungus.‡ The minute particles approximate and unite in twos, thus forming a double cell. (Perhaps these explain the figure-of-8 organisms pictured by Bastian). Moreover they sub-divide excessively rapidly, "so that the number produced can scarcely be expressed." The minute particles then unite in chains constituting leptothrix|| which is not a species, but a form of vegetation common to many species. In pure water, development can go no farther, nor after a few hours do the organisms continue to be formed. For further development the presence of a nitrogenous substance is necessary. The minute spherules (*micrococci*) are the special ferments of putrefaction. In the presence of sugar the spherule enlarges and becomes a nucleated cell (*cryptococcus*), identical with the yeast-cell.§ A very similar change takes place in oil fermentation. In milk the micrococcus elongates and forms parallelopipeds or staff-like cells ;¶ in acetic fermentation the cells assume a lancet-shape.** These ferments increase by division, and are classed by Hallier under the term *arthrococcus*. If we can accept the teaching of the foregoing evidence, fermentation and putrefaction are both due to the influence of a single agent—vitalised matter, which is transported from place to place by the air. We must believe that ordinary air contains minute masses of living matter—call these particles germs, germinal matter, protoplasm, bioplasm, or what we will ; that they are derived from the fructification of fungi which

* Fig. 17. † Fig. 18.

‡ Professor Beale figures the minutest spec of germinal matter as capable of growth into mildew.

|| Fig. 19. § Fig. 20. ¶ Figs. 22 and 23. ** Figs. 24 and 25.

can spring up wherever nitrogenous organic matter is in contact with air; that from such fructification it is not the visible spores but minute fragments of these which are the first causes of the subsequent decompositions; that these living molecules grow wherever they find a soil meet for them, and in different soil develope into different forms, and produce by their vital acts different effects.

I consider that we cannot fail from the evidence to conclude that there is a relation of causation subsisting between the organised forms observed in each variety of fermentation and the objective phenomena; the stages of their life are correlative with the chemical manifestations, and when they themselves die, the chemical manifestations cease.

On the other hand, we are asked to believe that the organisms met with are purely adventitious; that they are the offspring, not the cause, of the chemical changes. "The forces set in action by the chemical reactions determine organisation and life in the womb of the liquids in fermentation."* "Each fermentation *produces* a special cryptogamic vegetation." "The ferment is a body which determines fermentation, placing liquids in special conditions ordinarily favourable for the production of organisms. The term is applicable to all decomposable bodies whose contact can provoke new chemical combinations, and in this sense albuminoid substances occupy the first rank."

In this theory we are presented with a series of postulates each involving a paradox. To express this theory of fermentation in a diagrammatic manner:—

<table>
<tr><td rowspan="2">A ferment, i.e., a decomposable body whose particles are in a state of motion.</td><td>(a) Communicates motion to the particles of the fermentescible body: hence the chemical phenomena.</td></tr>
<tr><td>(b) Places liquids in special conditions for the spontaneous production of organisms: hence the vital phenomena.</td></tr>
</table>

* PENNETIER, Origine de la Vie, p. 256.

Of these two theories the first seems to present far less of difficulty than the second; it seems reconcilable with all the evidence which has been adduced.

It must be admitted, however, that the theory of Panspermatism has presented difficulties which it has been very difficult to explain.

Chief among the arguments adduced against it has been that derived from the action of heat on the phenomena of fermentation, which we will now examine.

CHAPTER X.

EVIDENCE ON THE THEORIES OF PUTREFACTION AND FERMENTATION AFFORDED BY THE RESULTS OF DESTRUCTIVE AGENCIES.

At a very early period in the history of the controversy concerning the origin of life, investigations were made with the intention of determining this question—Can vital organisms be found to develope under physical influences which are, under ordinary circumstances, fatal to any living thing? If so, there is a great difficulty in the way of accepting the germ theory. The Heterogenists have argued that living bodies are discovered after processes of physical destruction which it is *impossible* for life-possessing matter to withstand; therefore, by exclusion, spontaneous generation must occur.

The necessary conditions for experiments of this nature are (1) the subjection of fermentescible matter to such destructive agencies that vitality in it is impossible; (2) the prevention of any subsequent contact with it of an agent which may be a possible vehicle of vitality.

The agency usually employed for the destruction of all possible life in fermentescible fluids has been heat: the precautions against the admission of possible germs or germ-laden air have been various. The most simple of these

processes has been the subjection of the fermentescible fluid to heat, varying in intensity in different experiments, and its preservation in sealed flasks whence air was as rigidly as possible excluded. The originator of this method of investigation was Needham. Since his time it has been put in practice with varying methods for the exclusion of possible germs after the heating of the fluid.

The temperatures employed have varied in different experiments from boiling for periods ranging from a few minutes to 6 hours (Pouchet, Mantegazza, Child, Bastian), to 153° C., or 307·4 F. (Bastian.) The means of excluding possible vitality subsequently have been passing the air through a tube raised to a red or white heat (Pouchet, Wyman, and others), or through a tube containing strong sulphuric acid (Pouchet, Joly, Musset); or supplying only oxygen (Pouchet, Child, Mantegazza), or artificial air (Pouchet, Child); or preserving the boiled putrescible fluid *in vacuo* (Pouchet, Bastian). In all these cases organisms have been described as resulting.

In these experiments it would appear that the conditions would be fulfilled with the least liability to objection in the cases wherein the solutions were exposed to very high temperatures *in vacuo*. M. Pouchet filled a flask with a decoction of malt which had boiled for 6 hours, and hermetically sealed it. After 6 days a deposit, apparently of yeast, took place in the flask; on the 7th day, the external temperature having been suddenly raised, the flask burst with a loud report; there had been fermentation, and the microscope disclosed that yeast corpuscles had been formed.* Dr. Bastian has also performed analogous experiments with great care. In his first series, the fluids were boiled in small flasks for 10 to 20 minutes, and then by means of the blowpipe, hermetically sealed. After periods varying, in the different experiments, from 5 to 39 days, the flasks were opened, and the contents examined. In cases where infusions of animal or vegetable matter, or both, had an alkaline reaction, there were observed organisms

* PENNETIER, Origine de la Vie, p. 253.

evincing vital movements (monads and bacteria) together with some Torula-like cells. When the infusions had an acid reaction, there were vibrios, bacteria, interlacing network of leptothrix filaments, and, in some cases, higher unicellular organisms apparently in course of production.

Dr. Bastian proceeded to make similar experiments, using, instead of animal and vegetable infusions, solutions of saline substances. The salts in the solutions were used in the following combinations:—1. White sugar, tartrate of ammonia, and phosphate of soda; in this case bacteria, active monads, and "protoplasmic-looking" masses were discovered. 2. Acetate of ammonia and phosphate of soda: no organisms. 3. Oxalate of ammonia and phosphate of soda: monads and distinct fungus spores. 4. Tartrate of ammonia and phosphate of soda: densely interlaced and spirally-twisted fibre; confervoid-looking filaments, monads, and fungus spores; *Penicillium*. 5. Potash-and-ammonia alum with tartar emetic: fungus-spores and complete fungus of *Penicillium* type. 6. Carbonate of ammonia and phosphate of soda: moving particles, small *Torula* cells, spirally-twisted fibre-organism.

In further experiments Dr. Bastian subjected both vegetable infusions and saline solutions to a temperature of from 146° to 153° C. (294·8° to 307·4° F.) for four hours after all air had been exhausted, and the flasks had been hermetically sealed. The fluids employed were:—1. Turnip-juice: "monad-like particles" were observed; in one drop a "*Monas lens*" in active movement. 2. Solution of white sugar, tartrate of ammonia, and phosphate of soda: "two fresh-looking fungus spores were seen of the most unmistakable character," besides particles having a protoplasmic appearance. 3. Solution of tartrate of ammonia and phosphate of soda: a mass was observed "composed of a number of rounded and ovoidal spores, with mycelial filaments issuing from them in all stages of development." 4. Solution of carbonate of ammonia and phosphate of soda: a number of little figure-of-8 particles, and spherical or ovoid fungus spores were observed.

The chief conclusions to which this accumulation of data has pointed are considered by Dr. Bastian to be favourable to the doctrine of Heterogeny—that we are fully entitled to believe in the heterogeneous evolution of living things "as a possibility," and "that a new and direct evolution of organisable compounds may, in all probability,* be capable of arising, sometimes by isomeric transformation of the atomic constituents of a single saline substance, such as tartrate of ammonia, and sometimes by a re-arrangement of certain of the atomic constituents belonging to two or more saline substances existing together in solution. It is not only supposed that this may occur, but that even living things may subsequently be evolved therefrom when the solutions have been exposed, as before, in airless and hermetically sealed flasks to a temperature of 146° to 153° C. for 4 hours."†

In briefly considering these propositions we may divide the argument into two parts, the first being derived from the evidence of the supposed destructive influence of high temperatures on living matter, the second from the supposed impossibility of the pre-existence of germs in the fluids employed. It must be recollected that by the argumentation in favour of Heterogeny the method of exclusion is employed, and this requires the most prolonged and patient employment before its conclusions can be said to approach finality. Furthermore, its upholders must be prepared to substitute for the explanation of phenomena which may be derived from any other theory—another which shall be more satisfactory.

Let us, in the first place, accept as proved by the results of the experiments that living forms have been discovered, after the subjection of the fluid containing them to a temperature of 307·4° Fahrenheit. The affirmative proposition necessary to establish the heterogeneous evolution of these organisms is, that no living thing can in any state and under

* Dr. Bastian, in a foot note, does not claim this as proved.

† Nature, July 14, 1870, p. 228.

any conditions withstand a temperature of 307·4° F. without annihilation of its vitality.

It is probable that this would, according to their preconceived notions of the properties of living bodies, be at first sight adopted by most people. It is difficult, *à priori*, to believe that living matter could resist such a seemingly powerful cause of destruction. But it behoves us to consider the subject not solely according to our preconceived ideas, but to enquire as to the properties and the behaviour of living matter as derived from observation below the surface of ordinarily visible nature. And here we find many seeming paradoxes. We find that it possesses powers of persistence and of resistance which would certainly, *à priori*, appear paradoxical.

First, as to persistence. We know that vitality may lie dormant for a period which is almost inconceivable. Stramonium seeds, according to Duhamel, can develope after remaining 25 years under ground. Friewald asserts the germination of melon seeds after they had been kept more than 40 years. Pliny asserted that corn grew after it had been kept 100 years. Desmoulins obtained plants from seeds found in a Roman tomb of the third or fourth century. Finally, it is well known that corn found in some of the tombs of Ancient Egypt has germinated and grown to perfection, and that a squill bulb found in the hand of a mummy has, when planted in this age and in this country, grown and blossomed. In these cases it can, I think, scarcely be questioned that, remarkable as it may seem, the vitality (or term it what you will) of the various germs has slumbered during the protracted periods indicated. I do not think that the proposition that there has been in these cases actual death, with subsequent reviviscence, can be seriously sustained, least of all by those who uphold the heterogeneous evolution of living things according to definite and progressive stages, by which the identical original form could only by a miracle be attained. These facts alone are sufficient, I think, to show that we must rely on no *à priori* or surface-ideas for our conception

of the nature and properties of those bodies which possess vitality.

Then as regards resistance on the part of living organisms, especially with regard to temperature. First of all we have *direct* evidence as to the influence of temperatures on low organisms. We have abundant evidence that they can support very low temperatures, very high temperatures, and very rapid alternations of temperature. Bacteria and monads survive a cold of 23° F. for an hour, and often of 5° for a few minutes. The lowest organisms "possess for the most part," says an ardent supporter of Heterogeny, "a resistance often surprising to heat and to cold." * An experiment of M. Pouchet shows that certain of them can easily support rapid changes of temperature, "even a rapid transition of 100 degrees centigrade." In the hot Geyser springs, which reach nearly to the boiling temperature, unicellular plants have been found growing. And concerning lowly-endowed organisms, Claude Bernard taught—"that infusoria carefully dried lose all vital property, at least in appearance, and can remain thus for whole years; but when water is restored to them they recommence their life in the same manner as formerly, provided a certain degree has not been over passed in the desiccation."

Practically, however, the extreme limit of heat which it is found that *developed* organisms can bear in the presence of water has been fixed at 100° C.,—*i. e.* the temperature of boiling water,—and this by the upholders of either side. In dry air organisms are capable of withstanding a considerably higher temperature than when they are contained in fluids.

In the ovum and spore condition life-possessing matter, according to all the evidence, manifests a higher power of resistance than obtains in case of the developed organism. The zoosperms of the frog can retain their vitality in a cold not exceeding 24 degrees below freezing. M. Payen determined that the sporules of the *Oidium aurantiacum* resisted a moist heat of 248° F., and only lost their faculty of

* PENNETIER.

germination at a heat of 284° F. Pasteur asserted that spores of mildew *in vacuo* or dry air were fertile after exposure to a temperature of from 248° F. to 257° F., but he concluded that exposure for twenty minutes to half an hour to a temperature of from 260° F. to 266° F. completely destroyed their vitality. It is thus seen that organised material in the embryonic condition is capable of resisting temperatures which seem at first sight almost impossible. An argument to the contrary has, however, been urged, from the behaviour of known and recognised spores under such conditions. Pouchet observed that the spores of *Ascophora*, *Penicillium*, and *Aspergillus*, were completely *disorganised* by being boiled for a short time in water. So also Bastian showed that a fungus and spores heated in a sealed flask for four hours to 153° C.—that is to say, treated in precisely the same manner as the solutions which yielded him, in the case of infusions, evidence of life and organisation, were completely disorganised. "Not a single entire spore could be found; they were all broken up into small, more or less irregular particles." But it behoves us to enquire further as to the signification of this disruption. We can quite agree that, by the influence of the heat, the spore is torn asunder and dissipated into fragments, but it is another thing to assert that such fragments are bereft of all vital property. Observations have lately tended greatly to show that our notions concerning a "spore" must be modified. It is not like the seed of a phanerogamous plant, the nucleus of a single organism, but a collection of extremely minute individual particles, each of which may become a definite organism. Though, therefore, we may agree that there is an apparent disintegration of the visible spores, we need not subscribe to the view that every one of the individual particles has succumbed to the destructive influence. Disruption need in no way connote destruction. The divided polyp is not destroyed, but its fragments grow into fresh organisms, and a dismembered portion of a plant can become an individual tree. We may agree in the view that the spores may have lost the power of reproducing the plant whence they

were originally derived, but we know also that the surroundings and the conditions of pabulum are greatly changed by the influence of the heat, and that this may be a sufficient explanation. If one observes the ordinary appearances when mildew grows upon organic matter, one sees that, though a certain species (say *Aspergillus*, for instance) may be shedding its spores in all directions, these do not spring up as successive crops of *Aspergillus*—a species totally distinct in form succeeds it, and so on through the generations following. We are not bound to believe, therefore, from the apparent evidences of physical destruction, that every particle is rendered lifeless. Certainly we cannot conclude this from *à fortiori* grounds. To say that because higher forms would have lost vitality, therefore lower or embryonic forms must lose it likewise, would be equivalent to estimating the power of resistance to physical influences of a spermatozoon from the powers of resistance of a developed animal.

Dr. Bastian asserts that the vitality of vibrios and bacteria is destroyed by the boiling temperature. When infusions containing active bacteria and vibrios are boiled, the result is the disruption of the vibrios and the disappearance of all signs of life in the bacteria. "All their peculiarly vital acts have at once ceased, and they have henceforth displayed nothing but mere Brownian movements." It must, however, be remembered that such diagnosis of vitality is purely arbitrary. In the course of putrescence no one can tell when movements cease to be Brownian and commence to be vital; conversely, when the special bacterian movements have been caused by heat to cease, no one could assert that the movements of the *débris* were purely mechanical; nor, if all movement had ceased, could it be positively stated whether vitality had been annihilated or only paralysed.

In face of all the facts I do not think that the Heterogenists have proved their case that subjection to a heat of 153° C. is an absolute test of the absence of all vitality. When we see the extraordinary powers of persistence of

resistance of life-possessing matter, I consider that any single test which we may impose unaccompanied by collateral evidence cannot satisfactorily prove the absence of vitality. The very experiments themselves which are supposed to prove the impossibility of the pre-existence of vitality by the stringency of the adverse influences employed demonstrate how vital matter defies such adverse influences. Could one predict that even if low forms could originate, complete fungi could grow and fructify in the conditions of vacuum and of pabulum, which would seem with probability to be profoundly altered by the exceedingly high temperature? But not only so, in some of Dr. Bastian's experiments the growth of organisms seems to have been *favoured* by the conditions. As, therefore, with phanerogamous plants, there is a wide range of temperature conditions most befitting the perfection of different species, so I see no reason for denying to lower forms a wider range than our *à priori* views would have led us to imagine.

We will now turn to the second part of the argument advanced in favour of the heterogeneous evolution of the organisms found in these conditions, viz., the impossibility of the pre-existence of living matter in the materials employed in the experiments. The chief evidence in this direction is adduced by Dr. Bastian from his experiments with saline substances. He explored solutions of these with the result of finding not a trace of anything like an organism; no fungus-spore, germ, or egg of any kind, except in one, the neutral tartrate of ammonia. In examining crystals of the last-named salt, Dr. Bastian found in their very centre the following adventitious matter—cotton or paper fibre, "a small quantity of tenacious mucoid matter, containing refractive protein-looking granules of various sizes, a quantity of a colourless confervoid-looking mass, some of whose smaller filaments, 1-20,000″ in diameter, looked like a mere linear aggregation of irregular masses of protoplasm, though, in certain larger filaments continuous with these, it became obvious that the irregular protoplasm masses were contained within a delicate hyaline cylinder,

across which dissepiments were sometimes to be seen, as in very minute fungus-filaments; and, lastly, certain fungus-spores in almost all respects similar to those which have been met with in so many of the saline experimental fluids." The filaments, however, were never observed in recently-prepared crystals. The question is, whence the origin of these spores and confervoid filaments? They may have dropped from the air during the process of crystallisation, or they may have developed within the crystal. Dr. Bastian shows that the amount of the vitalised matter in the crystal, and the amount of gaseous bubbles which it evolves during its solution, progressively increase with its age. When a solution of the tartrate is progressively observed under the microscope, monads, bacteria, and *Torula* cells are found to develope. So, also, in the case of carbonate of ammonia. These spores make their appearance in all parts of the solution; their mode of evolution seems to show that they result either from a coalescence and re-arrangement of the invisible molecules of a pre-existing colloidal compound—*i.e.*, which was the product of an isomeric modification of the elements of the salt, or else through the development of innumerable but invisible germs disseminated through the fluid. "That such invisible 'germs' may have existed," Dr. Bastian adds, "I am quite disposed to believe—though I am as strongly inclined to disbelieve that these fluids were saturated with germs of veritable fungus-spores, which had emanated from some pre-existing fungus of the same kind."

It seems to me that the evidence adduced by Dr. Bastian is strikingly in favour of his opponents. The latter hold the universal presence of germinal molecules; Dr. Bastian shows them to exist in crystals by physical demonstration. That, once in a saline solution, such vital organisms can grow and propagate is no matter of doubt—it is admitted by either side. Pasteur showed that a salt of ammonia and the phosphates could become a perfect pabulum for *Torula* cells. The oxalates and phosphates have been shown by

* Nature, July 14, 1870, p. 220.

Hallier to be excellent media for the development of fungoid fibres, *Oidium* forms, mycoderms, and fructifying organisms.* The whole difficulty rests, therefore, with the earliest phenomena.

Dr. Bastian explored carefully his solutions, and found no visible spores of fungi. Could he seriously have expected to find the very obvious full-grown cells of *Torula*, or any large fungoid spores? He seems to have been entirely ignorant of the labours of Hallier and the German observers, for he treats as a mere theoretic possibility what they have shown on experimental evidence. Thus he says, "it is an undoubted fact which, though often stated, is not generally known or admitted, that *Torula* cells and other fungus spores may originate as minutest visible living specks, which grow and develope at once into fungus spores, instead of passing through the intermediate stages of *Bacterium*, &c." This at once disposes of Pouchet and the influence of the proligerous pellicle, and quite accords with the Panspermatist doctrine of Hallier. The minute living specks are the "schwärmer," which (as is shown by the cultivation of *Penicillium*, and not only by the theoretic possibility adduced by Dr. Bastian) are "capable of growing into such forms as their environing conditions may determine."

It being granted that germs *may* exist too minute for observation which, nevertheless, can be the primordial nuclei of higher organisms, the only difficulty which is acknowledged to remain is that we have just discussed. As Dr. Bastian puts it, "the existing state of our knowledge does not entitle us to believe that any such pre-existing living thing could continue to live after it had been exposed to a temperature of from 146° to 153° C. for four hours." And such view must be, as I have said, purely a matter of opinion.

It behoves us to enquire into the teaching of the negative as well as the positive results. That the proliferation of forms of life under restrictive influences such as have been

* Gährungserscheinungen, p. 95.

mentioned is exceptional is taught by the results of every labourer in the field. Privation of air is admitted to be a most potent cause in prevention of the appearance of organisms; or, to put it in another way, experiments in closed vessels are quite unfavourable to the demonstration of Heterogeny, because the natural and regular progress of the phenomena is paralysed. Increment of heat is another adverse influence, because the destructive agent impairs without destroying that organising force which is an essential property of organic matter. These are the modes of expressing the facts adopted by the Heterogenists; and MM. Joly and Musset, by actual experiment, prove that the organisms in a putrescible solution, submitted to ebullition, "are more simple and less numerous accordingly as the ebullition is prolonged." In fact, we must conclude with M. Pennetier "that the phenomena of spontaneous heterogenic generation, intense while their regular course is respected, are nevertheless manifest, though in successively lessening degrees, as causes of difficulty, are increased to finally cease when the phenomena of fermentation and putrefaction are themselves prevented." This as an *explanation* of the position to which science has arrived in this question, it is scarcely needful to say, is feeble in the extreme. It is merely a categorical expression of results which can be explained at least as well by the one theory as by the other.

Let us take a short retrospective glance in order to obtain an efficient explanation of the phenomena of fermentation and putrefaction from the point of view of the heterogenist. We see in each case a decomposition of an organic material; the first cause is a nitrogenous substance, whose particles are (though this condition is incapable of demonstration), in a state of motional activity. By the catalytic influence of this material, which it is capable of communicating, though itself exists in very minute proportions, the whole bulk of the organic substance is so changed that its elements are disintegrated, with the production of chemical phenomena, and, *pari passu*, the sub-

stance is rendered into conditions favouring its transformation into living forms. The possession of this faculty especially obtains in that condition of matter known as the colloidal. This is the term which has been applied by Professor Graham to distinguish substances of low diffusibility from crystalloids which have high powers of diffusibility. Colloids are characteristically complex and big-atomed; their molecules are easily susceptible of re-arrangement; they are unstable compounds. "Their existence," Professor Graham says, "is a continual metastasis. The colloidal is, in fact, a dynamical state of matter, the crystalloid being the statical condition. The colloid possesses ENERGIA. *It may be looked upon as the probable primary source of the force appearing in the phenomena of vitality.*"* The phenomena of putrefaction and fermentation, therefore, are catalytic; the appearance of this or that vital organism depends on the surrounding chemical conditions, not the chemical conditions in them. The ferment only places matter in such state, that by some occult union between it and the physical forces around it, there results the condition actual and potential which we express as vitality.

On the other hand, the germ theory attempts to account for all the phenomena as the results of the operation of organisms possessing life. Each theory is equally powerless to explain the great mystery of the nature of vitality. This theory supposes that living things can only proceed from living things, that there is no such possibility as the union of ordinary matter and ordinary force to constitute a vital organism. The phenomena of fermentation and putrefaction are alike due to the acts of life of organisms. Living molecules derived from living bodies are abundantly wafted about in atmospheric air, and pervade all materials that the air itself pervades. Wherever the face of nature presents a sufficiency of soil these molecules live and grow; but under different conditions, the resulting organism pos-

* Quoted by BASTIAN.

sesses different forms and has different functions. Nitrogenous matters alone form a sufficient food for ferments, hence they are essential to the initiation of the process.

The colloidal condition of matter exists on account of vital organisms, not vital organisms on account of colloids. The essence of the whole phenomena is the sum of the acts of life, death, and succession of generations of similar or diverse organisms—the only postulate is vitality. All the phenomena receive an efficient explanation in this hypothesis, with the striking addition that what is acknowledged to be invariable (the appearance of living forms) is rendered causal, whereas by the other it is purposeless. The only stumbling block adduced is the effect of high temperatures, which do not annul manifestations which are asserted with strong reason to be those of vitality.

Here I cannot help protesting against a mode of putting the question which has been adopted by all the advocates of Heterogeny with whose works I am acquainted. In the first place, they refuse to believe in the presence of germinal molecules which cannot be demonstrated to the eye. But assuredly they are here in equal difficulty, for they cannot demonstrate the first appearance of particles, whether dead or living, in a putrefying solution; nor can they show the mode of union between matter and force to constitute a living thing. On either side, therefore, collateral circumstantial evidence is required for proof. But, further, it is alleged that the onus of proof rests entirely with the Panspermatists. It is not for the Heterogenists to prove that germs do not exist, but for the Panspermatists to prove that they do exist. "The charge of proof in science rests with those who allege a fact" M. Pennetier quotes from Rénan, and he apostrophises the germ theory with one of those elegant compliments that so abound in his and other works of a similar school, as a "charming dream of another age; one of those abstract imaginary ideas which have no reality otherwhere than in the cerebral organ of those who put them forth."* The poetry of this apart, is the

* Origine de la Vie, p. 136.

position correct? I hold precisely the contrary. For the Heterogenists is the task to prove the negative. The positive proposition, "*Omne vivum e vivo*," is asserted by all the evidence of visible nature and by microscopic research, to those confines beyond which human powers cannot reach. That there is an exception to the seemingly universal law in the case of those organisms which are invisible, it must be the duty of those who embrace the theory of spontaneous generation to prove, or else to tolerate becomingly the scepticism of others. It behoves us seriously to weigh the only real objection to the reception of the germ theory—the resistance to the destructive agency of heat, and to enquire as to the effects of other physical agencies which may contribute to a solution of the question.

CHAPTER XI.

INFLUENCE OF TOXIC AND CHEMICAL AGENTS.

It was known, from very early ages, that certain substances added to matters undergoing fermentation or putrefaction put a stop to these processes. The process of embalming, for the prevention of putrefaction of the human body, is an example which dates from the greatest antiquity. The essentials seem to have been—first, evisceration; secondly, subjection to the inunction of oils and the application of various substances, especially aromatics, perfumes, salt, turpentine, soda; thirdly, protection from atmospheric action by an envelope of gummed cloth; or the body was simply treated with an antiseptic—asphalte. Another method or auxiliary employed for the preservation of bodies was desiccation, it being well known that putrefaction could not take place where there was no moisture. So, also, to check fermentation and keep it within due bounds, in the process of wine-making, thus preventing acetic fer-

mentation or putrefactive change, the ancients used a number of various substances—lime, gypsum, sea-water, turpentine or resins, aromatic herbs, spices and gums, dried salt; or a blazing pine-torch was plunged into the liquid.

Emanations from putrid material have been always looked on as sources of danger to health, and various applications have been made to putrefying materials with the object of arresting putrefaction. Sir John Pringle and Dr. Macbride, in the last century, classified such substances as arrested putrid emanations under the title of ANTISEPTICS: these observers, moreover, performed many experiments with regard to them, and endeavoured to ascertain their relative values. A high place was given to the *acids;* sulphuric, hydrochloric, acetic, citric, and tartaric, being about the order of their relative efficiency. But *ammonia and its salts,* as well as *potash* and *lime,* were also found to be very efficient antiseptics. Camphor was described by Sir John Pringle as of high antiseptic power. In later years creasote, charcoal, nitrous acid, chlorine and the chlorides,—especially chloride of lime,—sulphurous acid and the sulphites, have, as is well known, been extensively employed for the prevention of putridity and putrid emanations. A review of these agents cannot fail to show at once the wide diversity of the means employed to attain the same end.

There have been various theories advanced to account for the mode of operation of these various bodies in restraining putrefactive changes. In 1732, Petit concluded that astringents were the best antiseptics, and their action resembled the action of desiccation. Dr. Angus Smith * says—"Some substances, like the metallic salts and mineral acids, generally combine with the flesh or with portions of it, and, by making a permanent compound, prevent the action of air. Some substances, such as charcoal, condense the oxygen within their pores, and assist the destruction of the animal matter. Others, like permanganate of potash, give out the oxygen which they contain in large quantities, and thus hasten

* Disinfectants and Disinfection. Edinburgh, 1869, p. 30.

the formation of carbonic acid. Some of them, like chloride of lime, give out oxygen and other gases; and some of them, like sulphurous acid, act by taking oxygen from the substance to be disinfected, so that there is a *surprising variety in the modes of action*."

Mr. Crookes, in his valuable "Report to the Cattle-Plague Commissioners," adopted the following classification:—(1) *Oxidising Disinfectants*.—Such as ozone, which acts by directly oxidising organic material; permanganate of potass, which readily gives up its oxygen to organic matter; chlorine, which does so indirectly, by seizing upon the hydrogen of the water which is present and liberating the oxygen. (2) *Antiseptics*.—Such destroy the vitality of putrefactive germs. This includes by far the greater bulk of the substances employed.

Let us briefly consider the facts in relation to the theories of fermentation and putrefaction. If these were chemical processes, initiated by matter in a peculiar chemical condition and continued by progressive chemical changes, surely it would not be unreasonable to expect that the agents which controlled them should be in some sort of chemical relation to the putrescible substances and to one another. If putrefaction were a process of oxidation, we should reasonably conclude that agents controlling oxidation should have some sort of arresting power over it; but we find not only that this does not obtain, but that the converse is true, that some agents which tend to *increase* oxidation *arrest* putrefactive change.

Again, we should imagine that if a chemical agent arrested putrefaction or fermentation, in virtue of its chemical powers, there should be some sort of quantitative relation between its potential activity and the constituents of the substance itself. At least we should imagine that, in the one case, it should be present in sufficient proportion to produce some appreciable chemical change upon the bulk of the nitrogenous substance in the case of putrefaction, or the ferment or the fermentescible substance in the case of fermentation; but the facts are, that substances present in

such feeble amounts as to be incapable of any manifest action upon the organic material are nevertheless competent, and arrest all the phenomena of putrefactive or fermentive decomposition.

Let as turn to the theory which proposes to explain the phenomena on the supposition that they are produced by the acts of life of organised particles. We see, by very obvious data, that there is an analogy which cannot fail to be remarked between the phenomena of the two processes and the conditions which we know to be favourable to vital organisms. Air, light, warmth, moisture—these are the conditions most favourable to the changes. Conversely, circumstances antagonistic to life are unfavourable to the changes: such are an excess of heat or a very low temperature, dryness, physical injury (triturating yeast in a mortar spoils it for effecting fermentation). Gases which do not support life stop the phenomena of putrefaction and fermentation: such are hydrogen, nitrogen, carbonic acid. Furthermore, not only there is a definite relation between the stage of growth of the yeast fungus and its power of exciting fermentation, but, in the words of Professor Miller, "Everything that destroys the vitality of these organised bodies destroys their power of exciting fermentation." *

So also with regard to mildew formation. As M. Béchamp showed* whilst mildew was developed on every occasion when air acted on putrescible material, and no substance fatal to organisms was present, no mildew was observed when any substance which killed germs was present. But here Professor Hallier steps in and shows that many saline solutions which might *à priori* be deemed likely to exert toxic influences nevertheless, some to great extent, others slightly, permit the growth and development of fungi. Acetic acid when dilute permits growth, and its salts afford admirable pabula for *Penicillium* growths. The same again is true of oxalic acid and the oxalates. Vegetating fibres are also found in the alkaline and earthy

* Elements of Chemistry, Part III., p. 106. Ed. 1857.

† Comptes Rendus, 1863, p. 958.

chlorides, and in boiled sea-water.* The phosphates also are very favourable for vegetation. Tannin is a good pabulum, and cyanides readily permit growth. The mineral acids only when very dilute permit any vegetation; but their salts often allow growth of *Penicillium*, &c.

On the other hand, alcohol, benzin, and carbolic acid, are powerful poisons to fermentation-cells and mildew-formations.

Let us return especially to carbolic acid, and further examine concerning its *mode* of action, when, as is undisputed, it exercises its notable power in arresting putrefaction and decomposition. Starting from its observed power in arresting vitality, M. Lemaire† employed it to investigate the nature of ferments, using its toxic agency, instead of the destructive agency of heat as practised by so many other observers. Direct observations negative the hypothesis that carbolic acid owes its powers or any part of them to its coagulating power over albumen, or to any obvious interference with chemical phenomena. Suppose an organic fluid undergoing putrefaction or fermentation, with the concomitant growth of organisms, be treated with an aqueous solution of carbolic acid (one part to one hundred of its bulk), the organisms instantly die, and the arrest of the putrefactive or fermentive chemical changes is consentaneous with their death. If this be done in a vessel open to the air, the nauseous odours of putrefaction are gradually dissipated, and there is no further evolution of them; but if in a close vessel, though the process of evolution is checked, the fœtid gases remain; there is no deodorisation. So long as the fluid contains carbolic acid it is preserved from putrefaction, but when this is completely volatilised, the phenomena of decomposition return. Since, therefore, in the earlier part of the experiment all living particles had been killed, those which developed at a later stage must have been imported by the atmospheric air. Moreover, when putrescible substances do not

* This is confirmed in experiments which follow.

† De l'Acide Phénique, &c., p. 152. Paris, 1865.

undergo decomposition, the air in which they are kept containing carbolic acid, it is because their germs or molecules of reproduction are killed as fast as they are deposited. There is also a quantitative relation between the toxic action of carbolic acid and its power over fermentations, for the same doses that are observed to kill the living organisms, arrest the obvious phenomena of fermentation. "Thus," M. Lemaire says, "nothing is wanting for the demonstration: wherever microzoa or microphyta or their molecules of reproduction are in the presence of carbolic acid, life is extinguished, and with this disappear the chemical phenomena."* From this analogy certain pseudo-ferments are exempt. Myrosine, synaptase, diastase, pectase, and pepsine, are *chemical* agents inducing transformations essentially different from those produced by ferments. They do not require the element of time; their molecular changes occur at the moment of their union; they are unaccompanied by the manifestation of vital forms, and the influences which destroy vital manifestations do not impair their phenomena.

These facts have been independently examined by Mr. William Crookes, F.R.S., with an entire accord of results.† Mr. Crookes says, "The powerful action which carbolic acid exerts on the phenomena of life is the most remarkable property which it possesses. It may be looked upon as the test proper for distinguishing vital from purely physical phenomena, and in most cases its action is characterised by the certainty and definiteness of a chemical reagent."

It seems to me that it is difficult to resist the conclusions to which this evidence points—especially the establishment of the *essential* relation subsisting between vital organisms and the occurrence of fermentation or putrefaction. Carbolic acid acts *solely* by killing the organised bodies which are the intermediate agents between organic material on the one hand, and the inorganic ultimate products of decompo-

* *Loc. cit.*, p. 161.

† On the Application of Disinfectants in Arresting the Spread of Cattle Plague. Report to Her Majesty's Commissioners, 1866.

sition on the other. What bearing does the conclusion have on the controversy concerning the Origin of Life? While it puts aside all notions of intermediate chemical changes as favouring the spontaneous evolution of organisms, the objection may yet hold that the *initial* changes may yet be heterogenic, though the carbolic acid exerts its toxic power when once a molecule has acquired vitality. To obtain some evidence on this question, as well as to endeavour to fix the action of carbolic acid in its relation with other media, I have performed the following experiments.

CHAPTER XII.

EVIDENCE CONCERNING THE GERM THEORY DERIVED FROM EXPERIMENTS WITH CARBOLIC ACID AND OTHER AGENTS.

Experiment 1.—Into four wide-mouthed glass bottles of the same capacity I poured some freshly-made maceration of lean beef, the same quantity, one ounce, in each. One, A, I left merely covered by a cork. To the next, B, was added half a drachm of a five-and-a-half per cent solution of carbolic acid in water. In the next, C, the same amount of carbolic acid was mingled with 20 drops of glycerine. To the last, D, nothing was added, but to the cork was pinned a small piece of sponge, which was dipped in carbolic acid so that its vapour might become diffused into the air of that part of the bottle unoccupied by the fluid. The bottles were now placed side by side, under the same conditions of temperature, &c.

In two days the fluid of A presented a deep lake colour, and a yellowish white film was obvious on its surface. B and C were perfectly clear; colour, brownish-red. A whitish-brown precipitate was at the bottom of the vessel.

The following day the film became denser in A, and the fluid more dirty and troubled. B and C remained as before. D became brownish and slightly dull, no film.

The changes in the succeeding days were these:—A became still denser, and the film which first formed sank to the bottom, and was succeeded by another of a brown-yellow colour; B and C presented a very delicate, perfectly clear, transparent pellicle on the surface. The fluid of D, from its brownish appearance, became perfectly clear, and upon its surface appeared a pellicle as in B and C.

At the end of twelve days I found on opening the bottles that A was of extreme fœtor. B and C smelt only of carbolic acid; they remained as at the first. D presented no odour whatever of decomposition. Although nothing had influenced the fluid except the *vapour* of the carbolic acid, its whole bulk presented a strange contrast with that of A. Whilst A was of a dense reddish-brown colour, every drop being thick and troubled, D in its whole extent was clear and transparent.

On examination of the films in each case it was found that that of A was of a yellowish-brown colour, dense, thick, and friable. Under the microscope it was seen to consist of an aggregation of enormous numbers of granules or spherules—so-called monads. B presented a clear pellucid membrane which could be removed *en masse*. By microscopic examination in nearly its whole extent no structure could be discerned; it could only be distinguished from perfect transparency by the folds into which it was cast. Here and there, however, it entangled a few granular aggregations. C resembled B, with the difference that the pellucid membrane contained considerably more granular matter. D was more granular than B and C, but of the same transparent basis structure.

It is to be recollected that, in this experiment, no effort was made (by heat or otherwise) to destroy any possible germs which might be contained in the meat-infusion. That the evolution of living forms was greatly stayed by the means employed there could be no possibility of doubt.

The chief teaching is concerning the nature of the proligerous pellicle, which has by the Heterogenists been credited with extraordinary formative powers. The reader will remember that it is said to be composed of the earliest-living particles: in the instances where evolution was prevented, its true nature was obviously a mere film of coagulated albumen. In nearly its whole extent it was absolutely structureless, and, inasmuch as the well-established property of carbolic acid is to preserve organisms in their pristine shapes, it is fair to conclude that at no time did the structureless film (except in the isolated aggregations before noticed) contain granular particles, organic or organised. The presence of glycerine seemed slightly to hinder the preventive action on development.

Experiment 2.—It was intended to examine the influence upon vegetable development when various materials prone to present fungoid organisms were subjected coincidently to the influences of carbolic acid—(*a*) in the fluid containing the fermentescible matter; (*b*) in the air alone which was supplied to the materials.

It is necessary to explain that M. Pouchet adduced as evidence in favour of the theory of spontaneous generation the development of a peculiar *Aspergillus* which he himself discovered, and named, from the circumstances of its formation, *Aspergillus primigenius*.* Into a flat porcelain dish he poured boiling paste made from wheat-flour, so as to form a layer one centimetre thick. When this began to "set" he wrote upon its surface with a pencil dipped in a filtered maceration of nut-galls the words GENERATIO SPONTANEA The dish was then covered with a glass plate, and kept at a mean temperature of 24° C. for four days. At the end of that time the words which had been written appeared in bold relief and of a black colour, owing to the growth of an *Aspergillus* bearing black capsules on cylindric non-articulated stems. The reasoning is thus expressed. The germs of this fungus could not have entered with the paste,

* Fig. 26.

for this had fully boiled, and experiment shows that the *Aspergillus* spores are totally disorganised by a temperature below that of boiling water; besides, the spores are too large to have escaped direct observation. They could not have entered with the gall-maceration, because this had been filtered, and microscopic examination demonstrated their absence. They could not have entered with the air, or why should they not have covered the whole surface of the paste and not merely those portions which had been moistened by the gall-maceration? It is scarcely necessary to point out how subsequent investigation has invalidated every one of these positions. But it has seemed to me that the growth of this fungus presents singular advantages for experimental investigation. Its course of development is regular and uncomplicated, and its prominent characters render it very easy to be recognised. So I have frequently experimented upon its mode of growth under various conditions.

The following are the details of my experiment:—

I obtained three flat earthen dishes of equal size, and poured into each to the depth of a quarter of an inch a layer of boiled paste, made with ordinary flour. Then with a soft brush I painted over the surface of each in broad bands the following solutions—(1) filtered maceration of nut-galls; (2) common brewers' yeast; (3) syrup of currants; (4) wine (claret). Upon one (A) I placed a glass cover. Over the surface of the second (B) I poured 5 drachms of a one per cent solution of carbolic acid, and then affixed a glass cover. In the interior of the third (C) I suspended a piece of linen soaked with carbolic acid so as to give off the vapour, and then applied a cover as in the others. The three vessels were then kept at an equable temperature of 70° to 72° F.

In about two days, on the surface of A, that in which no carbolic acid had been introduced, a white feathery appearance was shown, especially on that part on which the gall-maceration had been applied. Soon afterwards little spots of blue mould appeared in other situations on A. B and C

remained, so far as the eye could detect, unchanged. On the fourth day that portion of A which had been brushed over with the maceration of galls was covered with a delicate white velvety pile, consisting of filamentous stems bearing on their summits minute black specks. B and C presented no obvious change. On the 8th day the whole were submitted to microscopic examination. The maceration-of-galls band of A presented multitudes of long, jointed filaments bearing on their summits capsules of globular form, containing multitudes of blackish sporules—the "*Aspergillus primigenius*" of Pouchet. Large spores of the *Aspergillus* were scattered over the whole field, and the capsules were shedding sporules in all directions.*

The same layer in B (very weak *solution* of carbolic acid) showed no trace of *Aspergillus*. But it was not destitute of evidence of vegetable organisation and growth. Small spores were seen less than one-fourth the size of those of the *Aspergillus*, as well as some *Penicilliums*, mostly short and imperfect, but a few branching.

The same layer in C (vapour of carbolic acid) showed in nearly its whole extent no evidence of organisation; but at one spot† there were seen cellular stems branching and terminating in globular, oval, or truncated apices—the *Aspergillus polymorphus*.‡

The other layers in A presented but little special variations. Feathery *Penicillia* were seen in almost every spot; the area where the wine was applied chiefly being occupied by round white dots, which proved to be aggregations of minute spherical spores. *Penicillia* were abundant everywhere; perhaps chiefly on the surface of the red currant syrup. B and C also showed some minute sporules with *Penicillia*, exceedingly less frequent than in A. C (vapour) showed some oblong cells but scarcely any fibrils.

The glass tops were now so re-applied that plenty of air circulated over all the surfaces.

* Fig. 26.

† It was probable that air uncharged with carbolic acid had entered at this point.

‡ Fig. 27.

In A growth and development occurred with extreme rapidity in every part. The generation of *Aspergillus primigenius* died and was succeeded by blue mould. *Penicillia* spread over every part of the field. Then the whole turned green, and after the lapse of a few days maggots appeared.

In B and C only, here and there, a few bunches of feathery *Penicillium* could be seen, the distinctive layers preserving all their original outlines, the paste basis being in each of a purplish tinge. In B (solution) at one small spot which seemed to have escaped the action of the liquid only, was there a patch of long feathery *Penicillia*. Very infrequently were seen small specs of *Penicillium* growth.

In C (vapour) there was not to the naked eye a trace of vegetable growth. In neither B nor C was there the least sign of animal development.

On the 23rd day I again submitted all to careful microscopic examination with the results appended.

Twenty-third day after preparation, fifteenth day after perfectly free access of atmospheric air, no more carbolic acid in solution or vapour having been since added.

I. *Layer covered with Gall Maceration.*

A. (Uninfluenced.)	B. (Carbolic acid, 1 per cent solution.)	C. (Carbolic acid vapour.)
Green mould, myriads of sporules, dense bands of *Penicillium* fibres, maggots.	Some *Penicillia*, a few fibres, infrequent minute spores.	No spores nor fibres.

II. *Layer covered by Syrup of Currants.*

A. (Uninfluenced.)	B.	C,
Green mould, myriads of sporules, dense bands of *Penicillium* fibres, maggots.	Spores abundant, no fibres.	No spores, nor fibres.

III. *Layer covered by Yeast.*

A. (Uninfluenced.)	B.	C.
Green mould, myriads of sporules, dense bands of *Penicillium* fibres, maggots.	Spores, some oblong cells, small fibres.	Abundance of cells of yeast unchanged, just as when first painted over surface, no growth whatever.

The chief teaching which can be deduced from this experiment concerning the action of carbolic acid in very weak solution and in vapour, appears to me to be the following:—

As regards the development of the specific fungus, Aspergillus primigenius. Complete prevention in both cases.

As regards the development of other fungoid organisms. Very marked repression, but not complete prevention in all cases.

Comparative action of (1) *weak solution of carbolic acid in direct contact with materials for developing fungoid organisms; and* (2) *carbolic acid present in the air supplied to such materials.* The latter by far the more powerful means of repression.

Experiment 3.—The materials were prepared for the development of the *Aspergillus primigenius*, and the steps were repeated with more stringent precautions against the entry of non-carbolised air.

The boiling paste having been poured into a flat dish, two glass covers, the one containing in its interior a small quantity of carbolic acid dropped from a crystal melted by heat and allowed to solidify at the upper part of the glass, the other untouched, were taken; these were then inverted over and embedded in the paste, and placed aside in a warm place. At the end of six days the results were observed.

Beneath the glass cover containing the carbolic acid (which of course could only have acted by reason of its volatility upon the contained air), there was no evidence of any organism whatever. Careful examination showed only minute granules, which aqueous solution of iodine coloured violet, and which were no doubt starch.

Beneath the glass cover containing no carbolic acid, there was exuberant growth of *Aspergillus*, filling up the whole space between paste and glass, its black capsules seen by the thousand, and its spores scattered in all directions.*

This was many times repeated with always the same result.

* Fig. 26.

The conclusion may be briefly summarised :—

Atmosphere supplied to prepared soil.	A. Containing no carbolic acid.	Result	A. Abundant vegetation.
	B. Containing carbolic acid.		B. No vegetation.

Experiment 4.—I thought it advisable to compare the action upon the air of various volatile media and chemical bodies under precisely similar conditions. I, therefore, prepared the paste and gall-maceration, and suspended within precisely similar glass covers the agents hereafter named.

The results are expressed in a tabular form. The order expresses the restrictive power over the appearance of fungoid organisms possessed by the various agents from the feeblest to the strongest.

Order.	Agent employed.	Appearances on 5th day.	Subsequent appearances.
1	Air unaltered.	Abundant growth of black-capsuled *Aspergillus.*	*Aspergillus* completely filled the vessel.
2	Chloride of lime.	Fibres of *Penicillium.*	This result was unlooked for, for by an accident the chloride of lime had actually fallen upon the prepared soil. Yet in and amongst its particles were developed growing fibres of *Penicillium.*
3	Sulphurous acid.	—	Soon after exposure to air, abundant and rapid *Penicillium* growth.
4	Ammonia.	—	Abundant *Penicillium* growth.
5	Ether.	—	Small island of mould appeared with abundant *Penicillia,* afterwards a few *Aspergilli.*
6	Chloroform.	—	After exposure many days *Aspergilli* began slowly to appear.
7	Camphor.	—	After many days *Penicillium* slowly developed and gradually covered the surface.
8	Iodine.	—	—
	Creasote.	—	—
	Phosphorus.	—	—
	Carbolic acid.	—	—

The results of this experiment show that many volatile bodies have the power of preventing the appearance of fungi when present in the air which surrounds the soil

upon which these under ordinary circumstances grow luxuriantly. The degree and the persistence of the influence of the various volatile media vary, however, considerably. Some, as ether, sulphurous acid, and ammonia, though effectually checking development while they are actually present in the atmosphere, leave when they are volatilised, or during their volatilisation perhaps, favourable conditions for growth. Chloroform and camphor have each a more persistent effect. Some act so persistently that no organism appears at all—that is to say, the paste dries up gradually to a yellowish semi-transparent cake resembling dry gelatine, and presenting no evidence of organisation whatever. For this peristency of effect I have found no agent so powerful as carbolic acid.

There is a further lesson to be learnt from this experiment. It appears, at least, to show that the chemical constitution of a volatile medium affords no indication of its energy in preventing the development of fungi. What agent could be expected more profoundly to alter the atmospheric conditions than chloride of lime? Its power as an oxidiser requires no comment. Yet it was precisely this that was inferior to *all* the other media, many of which could be shown to exert no perceptible chemical influence, in restraining the manifestations of vitality. The observation, however, agrees with that of Hallier, who found mycoderms, vegetating fibres, and *Oidium* forms, in the presence of chlorides of the alkalies and alkaline earths.*

Experiment 5.—Supposing, then, that the germs or factors of the vegetable forms entered by the air, it seemed important to endeavour to ascertain at what period they became deposited upon the putrescible material. Such might occur during the preparation of the materials for the growth of the *Aspergillus* at any of the following stages :—(1) At the time of the preparation of the maceration of galls (*a*) with the powdered galls, or (*b*) with the distilled water or during the maceration. (2) With the boiled paste. (3) During the time of exposure of the paste and gall solution together to the atmosphere.

† Gährungserscheinungen, p. 95.

To obtain some evidence on this point, I repeated every step of the process, exposing the several materials (the galls, the distilled water, &c.), to the influence of carbolic acid vapour, making strictly parallel experiments with other portions not so influenced. If I had found at any stage evidence of a check to the development of the *Aspergillus*, there would have been some evidence of the entry of the factors of organisation at the stage indicated. In none, however, did I find a sign that carbolic acid prevented or retarded the growth, except in the case where either the whole of the ingredients severally and collectively were exposed to the vapour, or where they were thus exposed collectively alone. In the intermediate stages of the process of preparation, there was no evidence of any influence whatever. It would, therefore, appear that the period of deposition of the germs was alone that during which all the preparations for the growth had been completed.

Experiment 6.—In several of the experiments before recorded the results seemed to show that there was less evidence of organisation in a putrescible fluid when a toxic agent was mingled with the air supplied to it than when the toxic agent was mingled with the fluid itself. This appeared to me so important as to require further investigation, for it appeared to have a very strong influence in determining the truth between the two theories. For if the doctrine of spontaneous evolution were true it would surely be more probable that the action of any chemical or toxic agent in repressing the manifestations of life would be most pronounced when mingled with the particles whence vital evolution was proceeding, and least so when only mingled with the atmosphere with which the fluids were in relation. On the other hand, if the germ theory were true, it would be more likely that there would be less fertility when the repressive agent was absent from the fluid and present in the superincumbent air, as the toxic agency would be directly exerted upon the air-germs.

I obtained a series of glass stoppered bottles of two ounces' capacity; to the stoppers of some of them I caused to be

fixed a small piece of sponge. The bottles were then each one quarter filled with filtered infusion of turnip, as used by Dr. Bastian in his experiments. To the fluid of A, there were added three drops of sulphurous acid; upon the sponge of A_2 was dropped the same quantity of the same agent. To the fluid of B_1 one drop of strong ammonium hydrate; upon the sponge of B_2 one drop of the same. To the fluid of C_1 one drop of ordinary rectified spirit of wine; to C_2 the same upon the sponge. To D_1 *four* drops of strong hydrochloric acid in the fluid; to D_2 *two* drops upon the sponge. To E a drop of creasote upon the sponge.

The stoppers were then fitted, and all the bottles placed together in precisely identical conditions of moderate warmth. They were thus left for seventeen days.

The unchanged infusion of turnip subjected to the ordinary air, dust alone being excluded, showed, in the course of two to three days, a universal opalescence due to bacteria and vibrios; after four days its surface showed fungus spores and spherical aggregations of granules. Slowly minute islands of mould appeared, and on the seventeenth day, when the contents of the other bottles were examined, the microscope showed enormous numbers of *Penicillium* filaments with fructification and innumerable spores.

The contents of the other bottles were then severally examined carefully with a quarter-inch Powell and Lealand lens, and with a one-fifth Smith and Beck, with both direct and interrupted illumination. I find that the latter method, whereby the minute organisms are seen of a delicate whiteness on a black ground, is by far the more suitable for this kind of investigation.

In A_1 (sulphurous acid in the fluid). Abundant vibrios and so-called bacteria in all parts of the fluid. At the surface *innumerable leptothrix chains and fungoid organisms.*

In A_2 (sulphurous acid in air). In fluid numbers of vibrios, as in former, but on surface *no fungoid vegetation whatever.*

In B_1 (ammonia in fluid). Mass of densely interlacing *Penicillium* and multitudes of spores on surface. Vibrios in fluid.

In B_2 (ammonia in air). On surface no fungoid organism whatever. In fluid abundant vibrios.

In C_1 (one drop of rectified spirit of wine in fluid). Multitudes of vibrios. On surface fibres of *Penicillium*.

In C_2 (one drop of alcohol to the air). Masses of fine interlacing fibres like *Penicillium*, but bearing capsules of globular or pyriform shape, enclosing granules in their interior. From the fineness of the fibres, these *Aspergilli* resembled those figured by M. Victor Meunier as occurring under restrictive conditions, and called by him *Aspergillus Pastorii*; but the fructification differed, the spores of the latter being on the external surface of the capsules. It is rather a fine-fibred variety of the *Aspergillus ramosus* of Pouchet.

In D_1 (four drops of hydrochloric acid to the fluid). Solution perfectly clear. No organisms discoverable.

In D_2 (two drops of hydrochloric acid in the air). Vibrios. No surface vegetation.

In E (creasote in air). No vegetation whatever. Vibrios.

In all the cases, therefore, with the exception of that in which alcohol was employed, there was an entire suppression of all fungoid organisms, whilst in the collateral experiments, in which the same agents were commingled with the fluid, these were abundant. It seems difficult to arrive at any other conclusion than that the agent when present in the air was a direct poison to the germs therein contained, whilst by dilution in the fluid its powers were enfeebled, and the atmospheric germs found a not unsuitable soil.

It is to be noticed that, in all the cases except that in which hydrochloric acid was used in sufficient quantity to arrest all vitality, myriads of active vibrios and bacteria existed in all the fluids. These I have frequently found when all putrefaction has been entirely arrested. I am induced to think, with Hallier, that they have no causal relation with the process.

Experiment 7.—It has been urged,* as an objection to the view that carbolic acid operates as an antiseptic in virtue of

* See pp. 27, 30.

its power as a poison to low organisms, that experience shows it to hold an inferior position as a poison to that of other agents whose faculties as antiseptics are less pronounced. I have shown, however, that a fallacy underlies this argument, in the fact that many of the agents quoted as having higher toxic powers are also, in the like conditions, better antiseptics. Moreover, the experiments were on animal vitality only; they did not touch on *vegetable* development, which the observations already cited have shown to have a close relation with septic change.

To investigate the action of (1) strychnine and (2) hydrocyanic acid, I prepared the soil as before for the growth of *Aspergillus primigenius*, on two capsules, and covered the whole surface of the one with a solution of strychnine (1 to 100 of water), and that of the other with a solution of hydrocyanic acid (strength of the British Pharmacopœia).

Examined five days afterwards, (1) the soil to which strychnine had been added showed everywhere the growth of *Aspergillus* in the utmost luxuriance (see fig. 28); (2) that treated by hydrocyanic acid showed no evidence of growth.

Strychnine is in no sense antiseptic. Liebig has shown that the first effect of strychnine upon the fermentation of sugar is to *accelerate* the process. During the first six hours, fermentescible mixtures with strychnine added evolved much more gas than the standard; subsequently there was retardation.

Hydrocyanic acid, however, has a marked power in repressing fermentation. "A very small quantity of hydrocyanic acid," says Liebig, "retards and prevents fermentation." * The fluid filtered from yeast-cells, if mixed with a trace of prussic acid, remains perfectly clear, and does not become mouldy. Schönbein has shown, however, that the yeast, though preserved inactive during the presence of hydrocyanic acid, becomes active again, even after a long time, if the acid be washed away. This action of hydrocyanic acid requires further investigation. The faculty of

* Annalen der Chimie und Pharmacie, February, 1870.

repressing the evolution of vegetable forms does not pertain to the salts of hydrocyanic acid. Hallier even says they are favourable to fungoid elements,* and he found vegetating fungus-fibres in sulphocyanide of potassium, with other fungoid growths. It appears very probable that only the free *volatile* acid is capable of restrictive action, and it is very probable that it operates by influencing the atmospheric conditions.

Conclusions.—In the foregoing chapters I have endeavoured, though I am well aware that the detail is imperfect, to present a faithful picture of the conditions of the questions of the origin of life and the nature of the phenomena of putrefaction and fermentation. It has been the fashion among many medical philosophers to regard the germ theory as a hasty generalisation from imperfect data. I believe I have adduced sufficient evidence to show that its supporters cannot be accused of impatience,—that for earnestness of thought and zeal in experimentation they are not inferior to those who differ from them in interpretation.

In these questions that latitude of opinion which the cultivators of Science should never deprecate ought to be especially conceded by those who conscientiously take up the contest. Opinions concerning the force-attributes of matter will be various, according to the bias of the minds of men, and views which are distasteful may be repudiated with insufficient cause. But, given all this latitude, I consider that the germ theory, whilst nothing has been conclusively established against it, is so strongly supported by the convergence of different kinds of observation and different modes of thought, that a dispassionate observer cannot fail to receive it as that highest expression of probability that in Biology constitutes a law.

By germ theory I mean the doctrine that the decomposition of organic material, in the processes known as putrefaction and fermentation, is due to germs, and that

* "Cyanverbindungen sind sehr gute Nahrungsmitter für Pilze." Gährungserscheinungen, p. 96.

these germs are minute particles of living matter derived from a pre-existing living parent.

Concerning minor points and details there is much room for doubt, and much encouragement for future investigation. I myself incline to hold that the active agents in inducing the changes are vegetable, not animal, structures. The motile bacteria and vibriones which are observed in the early stages of organic decomposition—inasmuch as they are so universally present that they cannot be considered special to any process, as they can be traced to no form of future development, but may be observed to live their term of life, to die, and to undergo putrefaction like other organic material, and as they may be observed in cases wherein all putrefaction is arrested—I consider to be non-essential to the processes of decomposition. On the other hand, I see that fungoid elements play an essential part in the processes; when they are present the phenomena are manifest, when they are absent the converse, agents which quench their vitality arrest the objective signs.

Fermentations can, according to my view, be distinctly divided into two classes:—I. *Fermentations in which there is no reproduction of the ferment.* II. *Fermentations in which there is reproduction of the ferment.*

In the first class there is a mere re-arrangement of the molecules, usually without any violent change in the physical constitution of the substances acted upon. It comprises the changes induced by pepsine upon albumen, by diastase upon starch, by emulsine on amygdaline, &c. It corresponds to the class "fermentations à elements non figurés" of Gautier. The changes are produced by a soluble or quasi-soluble organic compound, and are not of necessity attended with the appearance of any organism whatever. The circumstance which abruptly divides them from the second class is this—that the ferment inducing them does not become multiplied and reproduced in the process, but tends rather to exhaust itself. A fragment of diastase will change a considerable quantity of starch into glucose; but when the change is completed a fragment of the resulting

compound will not produce, upon succeeding portions of starch, a like change.

In the case of alcoholic fermentation, on the other hand, the original power of inducing the fermentation is transmitted to the yeast through successive generations.

The first class, then, includes fermentations not reproductive; and as the ordinary notions concerning fermentations associate with the process the idea of a reproduction of the ferment as an essential element, I think we should exclude these transformations from the category of true fermentations.

True fermentation, in my opinion, is a decomposition of an organic material which has a certain uniformity of composition, initiated by the vital acts of fungoid organisms. Whether these organisms effect the whole decomposition by their acts of life, "purs et simples," or whether their activity once manifested, their influence in decomposition is multiplied by a quasi-catalysis, is, to my mind, a secondary question, as yet undecided.

Putrefaction I consider to be a process analogous to fermentation occurring in a material of more complex constitution than obtains in the latter, or in a material of mixed composition. The initial changes are induced by fungoid organisms, which vary according to the material—as it comprises substances capable of the various kinds of fermentation. The material in putrefaction, however, affording a more fitting pabulum for forms of animal life, the complications due to the appearance, vital acts, and mutual decompositions of animalculæ, are superadded to make the process still more complex. The fœtor is chiefly due to the evolved sulphur compounds.

CHAPTER XIII.

PRACTICAL APPLICATION OF CARBOLIC ACID IN DESTROYING NOXIOUS FUNGI AND INSECTS, AND IN PREVENTING PUTREFACTION.

The views which have just been enunciated as to the mode of action of carbolic acid are daily receiving corroboration from the results of its actual employment.

Mildew.—In the case of mould and mildew, the presence of a very small quantity of carbolic acid suffices to arrest its formation. An open bottle of carbolic acid in a mouldy cupboard will be a perfect means of prevention (Lemaire). The objection to the use of carbolic acid to prevent the occurrence of mildew on substances destined for food is its powerful odour; but this objection is partly overcome by the ease with which it is volatilised and dissipated, by the fact that a very small quantity only is required to produce its inhibitive action, and by the knowledge that it is only necessary (as I have lately pointed out) to affect the air which is supplied to the surface of the material. Thus jellies and conserves of fruits and vegetables can be preserved by covering the jar containing them with paper moistened with aqueous solution of carbolic acid. Of course, if they are destined to be preserved for a very long time, the volatilisation of the carbolic acid into the surrounding air must be prevented, by applying over the surface of the carbolised paper animal membrane, or some impermeable material. Exposure to the air for a short time, after the jars are opened, will serve to dissipate most of the odour of the carbolic acid, which only affects the superficial layer of the jelly, and this can be removed if it be so desired. The heat usually employed to liquefy the jelly, before it is poured into moulds, also contributes to remove any odour. A similar proceeding may be adopted to preserve biscuit or any such food which is apt to turn mouldy.

On a large scale, however, I should counsel the transmission, throughout the vessel in which the substances are

preserved, the *vapour* proceeding from boiling carbolic acid, previously to the hermetic closure.

Carbolic acid has been successfully used to prevent the mildew which is apt to form on the specimens in collections of Natural History. It thus arrested the threatened destruction of about 15,000 *Coleoptera* in the Museum of Natural History in Paris. The carbolic acid was applied by washing the specimens with a solution of it, as well as by allowing it to evaporate in the boxes in which the specimens were enclosed. The Director, in his letter to M. Lemaire, who suggested the plan, thanks the latter for having come to his aid, by giving him the means of rescuing from certain destruction a collection which cost him twenty years of continuous labour. M. Armand Gerber confirmed these results. He found, as I have also shown, that strychnine and brucine, though destroying animalculæ, do not prevent the production of mildew, while metallic salts spoil the specimens of insects by the efflorescence they leave on crystallisation. Pure carbolic acid must be used; the impure turns brown in the air, and spoils some of the delicate colours of the specimens. The solutions recommended are 10 parts of carbolic acid to 100 or 150 of ether. It was found that ants will not touch the carbolised specimens, though they readily devour those which have been left uncarbolised. A similar method was put in force by the late Professor Gratiolet, who advised that such collections should be kept in carbolised air in glass cases rendered air-tight by dipping into a groove containing mercury.

The mould which developes in ordinary writing ink, rendering it thick, can be prevented by the addition of a drop or two of a very weak solution of carbolic acid.

Fungi Developed upon Living Plants.—It is well known that under certain conditions fungi are developed upon the roots, bulbs, stems, leaves, fruits, and seeds, of living and growing plants; they can, indeed, invade every part of their tissues.

The question of the relation of these fungi to the diseases, as well of plants as of animals, will be debated in subsequent chapters. At the present it is sufficient to point out that

their existence is undoubted, and that their influence upon the growing plant is a noxious influence.

In the vineyards of wine-producing districts there frequently occurs severe loss, on account of the ravages of a disease which attacks the vines. Upon the diseased vines exists, in vast numbers, a fungus in the form of *Oidium*. Numerous efforts have been made to destroy this *Oidium;* among the most successful has been fumigation by means of burning sulphur, the sulphurous acid evolved directly poisoning the fungus. It has been said, also, that soot (charged necessarily with tarry products) has kept away the disease, when it has been sprinkled over the ground. M. Le Beuf, of Bayonne, in 1861, employed the chalky material used for the purification of gas, which was thus charged with crude oils of tar. Having mixed this material with water he sprinkled, by means of a brush, a fine vine (Chasselas) attacked with *Oidium*, and observed that the disease was arrested not only in the vine itself, but in the individual grapes. Over that portion of the vineyard which was treated in the manner indicated the disease was completely stayed; in the other portions it continued its ravages.

Solution of carbolic acid, even as dilute as one part in a thousand, will destroy the *Oidium*, but it will destroy also the vine. Experiments, however, show that in some instances the disease has been arrested, without injury to the vine, by dressing the soil with carbolised earth (2 parts of crude oil of tar to 100 of earth) spread upon the soil for about an inch in depth, and renewed in ten days. M. Lemaire also asserts that a similar plan stayed the ravages of the *Uredo candida*, a fungus attacking a crop of salsify (*Tragopogon porrifolius*). In this case the disease was very severe, and the *Uredo* had been demonstrated by microscopic examination.

Noxious Insects are readily killed by a weak solution of carbolic acid. A proportion of 1 : 100 of water may be used to kill ants, &c., and the presence of a very small quantity suffices to keep them away; these insects refuse to cross a line

drawn on the surface of the ground by means of a brush dipped in carbolic acid solution until the whole has disappeared by volatilisation. Thus ants, slugs, and crawling insects of all kinds can be prevented from attacking trees; it is better to paint around the trunk of the tree crude oil of tar, as this, on account of its slight volatility retains its influence much longer. M. Lucien Biard wrote thus to the Minister of Public Instruction in Paris:—"One of the plagues of Mexico, especially in the temperate quarter, results from ants. They exist in such numbers in the houses that cupboards and pantries become positively useless. Turpentine plentifully sprinkled drives them away for a few hours; but a mere line drawn by means of a brush dipped in carbolic acid is an invisible barrier, which they never cross. These ants are migratory; they may be seen in Mexico to march in close battalions along the roads. When one of these invasions threatened us, my pupils delighted themselves in sprinkling a little oil of tar before the door. The force then made a half-turn as if they had met with an obstacle, to the great astonishment of the Indians and curious onlookers. Thanks to the oil of tar I have freed my house from those unwelcome guests, whose depredations I had submitted to for ten years."*

Fleas and bugs may be readily destroyed by washing the furniture and the floor of the rooms infested with them with a 5 per cent solution of carbolic acid; whilst a vaporiser may be used to throw the fluid in the form of spray into the crevices.

A similiar proceeding may be adopted in case of moth. I thus saved a valuable piece of furniture from absolute ruin. To make assurance doubly sure, I here used a strong solution of carbolic acid, and enveloped the whole with a thick covering, so that the agent might penetrate everywhere in the form of vapour. Exposure for a week or two to the air removed all traces of odour, and not a single moth reappeared, though the affected article has long taken its former place.

* LEMAIRE, "De l'Acide Phénique," p. 260.

Preservation of Growing Crops from the Attacks of Insects.—The use of carbolic acid to this end has been many times suggested, but it is necessary to take certain precautions in its employment, and to remember that it is capable of being destructive to the vegetable growths as well as to the insects which infest them. The difficulties have, however, proved to be far from insuperable.

In the first place, we must recall the action of carbolic acid upon grain and seeds.

Lemaire found that a solution of carbolic acid containing 1 per cent destroyed the germinating faculty of lentils, beans, barley, oats, &c. When the solution was weaker (two parts in a thousand) the seeds might be preserved, and after having been exposed to the air and well washed, would grow, though at first somewhat less rapidly than normal grains. But it was an ascertained fact, that no grain would germinate if the fluid supplied to it contained one or two parts in a thousand of carbolic acid.

To explain these facts, M. Lemaire has enunciated a rather startling hypothesis. He holds that infusoria are as necessary to the germination of vegetable seeds as spermatozoa are to the animal ovum. He describes infusoria as constantly present when germination occurs, and absent when by reason of the presence of carbolic acid it is prevented; though if this be true it is far from establishing the relation of cause and effect. As we have seen, the bacteria and vibrios cited by M. Lemaire appear in the conditions of warmth, moisture, and presence of organic matter, which also conduce to the germination of seeds. Nevertheless the view is not altogether *primâ facie* impossible. Newport found that there was a certain relation between the number of spermatozoa supplied to a batrachian ovum and the integrity and vigour of the embryo. Many observations have shown that in the fertilisation of flowering plants a certain *amount* of pollen is necessary to produce a vigorous seed, and an insufficient amount produces only imperfect seeds.* It might be possible, therefore, that in

* Cf. DARWIN, Variation of Animals and Plants, in Vol. ii, pp., 363, *et seq.*

the germination of a seed living particles might supply some of the formative matter necessary. But, certainly, this is in no sense proved. The carbolic acid which affects the infusoria would at the same time affect the seed.

A far simpler and more probable theory is to my mind the consideration that the carbolic acid is a poison to the embryo-plant in degrees varying with its concentration. Within a certain dilution it completely kills it, rendering it ever afterwards incapable of germination. Present in less quantities it is insufficient for this purpose; but it is sufficient to prove a protective covering to the contained embryo, and to slightly retard growth. It is certain that a given proportion of carbolic acid endangers the seed. With certain precautions, however, itself, or an agent owing its properties chiefly to it, may be employed with great advantage to secure crops from the ravages of insects. For this purpose two methods can be adopted—incorporating the agent with the soil or washing the growing crop with a carbolised solution.

The method recommended by M. Lemaire, when it is desired to sow the seeds for a crop or to transplant growing vegetables, is to spread over the soil a thin stratum (about an inch) of *carbolised earth.* This is composed of—ordinary tar, 2 parts; common loam passed through a sieve, 100 parts. Sand or sawdust may be substituted for the loam. The carbolised earth is dug into the soil a spade's depth, and the sowing or transplanting is at once practised. Those insects which are not destroyed immediately quit a soil thus prepared. This inhibitive influence, M. Lemaire says, lasts for two months, and then the insects begin to return, ants and earwigs being the first visitors. The growing plants seem at first to be somewhat less vigorous than those in ordinary soil, but soon they assume a comparatively greater appearance of health. Trees, shrubs, &c., may be preserved from insects by surrounding their roots with a circle of carbolised earth. There is so much evidence of the fact that crops can be preserved from noxious insects without themselves suffering in any way, that it is to be desired that

it should be much more commonly employed to this end; for there is no doubt that the loss entailed in crops by the ravages of insects is in the aggregate a very heavy one.

Preservation of Seeds.—There is also no doubt that much loss results from the destruction of seeds by mildew, inopportune germination, and such causes. It has been said that the depredations of insects alone give rise to an average annual loss of 20 per cent in France.

Seeds can be perfectly preserved in ordinary air containing carbolic acid vapour. If the seeds be kept in close vessels containing carbolic acid on a suitable surface for its evaporation, or in chambers in which carbolic acid is allowed to evaporate, perfect immunity from mildew and from insects is attained.

Prevention of Putrefaction.—Preservation of Food.—It is well known that one of the most common methods of preserving food in a state fit for alimentation is that known as "smoking." It is thus that bacon, hams, various kinds of fish, &c., are preserved in a wholesome condition. The agents which give this power of conservation in such cases are the tar acids or creasote compounds derived from the smoke in which, during the process of curing, the articles of food are suspended. Thus, carbolic acid and its congeners have been used unwittingly for ages.

Besides these methods, drying, salting, and exclusion of air by preservation in solid hydro-carbonaceous matter, or by enclosing in a vessel, heating and hermetically sealing, while steam is issuing forth, have been the chief methods employed for the preservation of food.

The objections to these processes are—that *salting* hardens the fibre of meat, rendering it indigestible, besides conferring upon it the saline taste, which is not suitable to all persons; *drying* also renders the substance more difficult of digestion; *smoking* confers an empyreumatic taste, and is practicable only in cases of certain kinds of food; *preservation in close vessels* whence air is excluded is not always practicable and is often uncertain. The usual method adopted for the preservation of meat, vegetables, soup, &c., for long periods,

especially for use on board ship, is to enclose the materials to be preserved with water in a tin vessel, upon which, after the introduction of the materials, a cover perforated with a single small aperture is soldered. The tins and their contents are now subjected to a strong heat for a certain time, and whilst a jet of steam is issuing from the small orifice, the latter is suddenly sealed by a lump of solder. The tins have subsequently to be carefully tested, for there are many which have to be condemned on account of imperfection. Thus, though this is a most valuable process there remains in it an element of uncertainty, and consequently of loss. Moreover, the process is somewhat expensive. A simple and effectual method of preserving food is of extreme importance for the national welfare.

Many experiments have been made with carbolic acid with reference to this question. A piece of meat, the surface of which has been covered with pure carbolic acid, can be preserved untainted for a very long time, but its external portions are rendered hard, nauseous, and useless. If instead of pure carbolic acid a mixture with oil in equal proportions be employed, the results are more satisfactory. Lemaire preserved thus a piece of pork weighing about $2\frac{1}{4}$ pounds for four months, and found it after having been cooked perfectly wholesome. A less proportion of carbolic acid mixed with oil must not be employed; oil so far modifies the properties of carbolic acid as to entirely destroy its antiseptic power when it exceeds a given proportion. A 5 per cent aqueous solution of carbolic acid most effectually prevents all putrefaction, but a 5 per cent oily solution in no way prevents it. A piece of meat dipped in such a compound rapidly putrefies.

An attempt was made to consign from La Plata to Paris meat treated with a mixture of olive oil and carbolic acid, the latter being in insufficient quantity. The result was, the consignments arrived in a putrid condition, and were at once confiscated and destroyed. When equal parts are used of oil and acid the antiseptic effect is satisfactory. Sausages the external parts of which have been thus treated have been kept for a very long time perfectly wholesome.

The employment of carbolic acid to preserve meat on a large scale has been successful. M. Lambert has thus consigned it in perfectly wholesome condition after the lapse of nine months. The meat was sent from a very large establishment at Monte Video, at which it was customary to slaughter from 250 to 300 animals every day. The process adopted consisted :—(1) In getting rid as far as possible of the serous fluids of the meat; (2) pressing the meat, previously freed from bone, into a compact mass by means of a hydraulic press, each mass weighing from 1 to 2 cwts.; (3) enveloping each mass with some canvas-fabric, which was afterwards coated with a compound of tar with 20 per cent of carbolic acid. The success of this plan was such that the meat was preserved, although it was exposed to very high temperatures; and after arrival in Europe, and when it had been washed and soaked for some hours, it was perfectly fit to be used for food. Such is the process adopted by MM. Lambert and Biraben; five years ago over 25,000 bales thus prepared found a market in England and Ireland. The source whence this food is derived will take long to become exhausted. M. Lambert says, "the last statistical enquiry ordered by the Government of the Republic of Uruguay in 1864, shows that in the provinces of La Plata alone, there are twenty-three millions eight hundred thousand head of horned cattle, which multiply at the rate of 12 per cent per annum." *

Enough has been cited to show that carbolic acid has successfully fulfilled a very important function in preserving food in a state fit for proper alimentation. Experience may, however, improve upon the mode of its application. Used in the manner indicated, carbolic acid prevents the development of all those fungoid organisms upon which the progress of putrefactive decomposition, as we have shown, depends.

Carbolic acid fails to exert its antiseptic power in case of substances which abound with liquid fat. This was

* LEMAIRE, De l'Acide Phénique, p. 304.

observed in a rather strange way by the late Professor Gratiolet: he found that crabs especially, though kept in a strongly carbolised solution, rapidly putrefied; this might, he considered, be due to the fact that crabs are possessed of a very large liver full of oleaginous material. I have shown elsewhere that oil enters into a definite composition with carbolic acid, impairing its inhibitive effect on fermentation. But this is I think not the whole reason of the spread of putrefaction in the presence of oil; for the oil itself enters into oleaginous fermentation, and the oil-particles prevent the direct action of the aqueous solution upon the *Micrococci* which are developed, and are the active agents of the oil decomposition.

Preservation of Entire Animal Bodies after Death.—If the body of an animal after death be injected by the arteries with a saturated watery solution of carbolic acid, putrefaction is prevented for a long period—until the volatile acid has been dissipated in the air. When, instead of pure carbolic acid, an emulsion of spirit of wine and crude oil of tar is used, the effect is much more permanent, because the volatility of the crude compound is far less than that of the pure acid. If the animal injected be already in a state of advanced putrefaction, the course of that putrefaction is immediately arrested. The bodies when left in the air become dry but never putrid. "Already," wrote M. Lemaire, in 1865, "more than five years have elapsed, and animals which have been injected with tincture of coal tar, in spite of their exposure to the air, present no sign of putrescence, only pediculi have attacked the integuments."* This method can readily be adopted for the preservation of specimens illustrating natural history. It has, however, a very important application for the *preservation of subjects for anatomical study*. In this country, where there is constant outcry concerning the difficulty of procuring a sufficiency of subjects for dissection, it appears to be thought little worth while to endeavour to preserve the few in the best

* De l'Acide Phénique, p. 310.

possible condition for anatomical study. When I was a student at the Ecole Pratique, in Paris, on the other hand, where anatomical subjects were plentiful, it was common for methods to be adopted to preserve the tissues. Surely the arrest of putrefaction is worth accomplishing as well for the greatly increased facilities of demonstrating the structures as for the prevention of those horrid and pestiferous odours which load the air of a dissecting room. The method of conservation adopted in times past has usually been injection through the arteries of a solution either of chloride of zinc, as first practised by Franchina, of Naples, or of hyposulphite of soda. Both these had their inconveniences —they spoiled the scalpels, and the chloride of zinc, while preventing the odour of putrefaction, did not always prevent the development of fungi. Moreover, the tissues were by the latter rendered inconveniently hard. The influence of the hyposulphite of soda is not long persistent. A solution of carbolic acid was first used for the injection of bodies in 1851 by Mr. Crace Calvert, in Manchester; these were perfectly preserved for several weeks. Lemaire advises that a one per cent aqueous solution be employed. Except in high temperatures, the influence will last for two months; and the effect can always be kept up by washing the surface of the specimen with a 5 per cent aqueous solution. This method, besides being very satisfactory, has the further advantage of being very cheap, and the volatilised acid adds to the hygienic conditions of the dissecting room.

Carbolic acid solution also serves to preserve specimens immersed in it as well as the greatly more expensive spirit of wine which is commonly employed. The vessels containing the specimens must be closed so as to prevent the escape of the volatile acid into the air.

Entire animals or birds, with their skins and plumage in perfect condition, can be preserved in hermetically closed vessels containing volatilised carbolic acid.

Employment of Carbolic Acid to facilitate Medico-Legal Investigations.—The injection of dead bodies with crude carbolic acid for the purpose of preserving them from

putrefaction may be of great service in two classes of cases. *First*, for preservation for the purposes of identification. *Second*, for facilitating post-mortem examination, especially in cases wherein the difficulties of the operation are increased on account of the advanced stage of decomposition.

CHAPTER XIV.

ACTION OF CARBOLIC ACID ON INOCULABLE VIRUS.

M. Lemaire records the following observations. He caused the ear of a guinea-pig to be stung by two bees. A few minutes afterwards he applied liquid carbolic acid to the part; the animal showed no signs of distress, nor were there any phenomena of inoculation. When, however, the other ear of the same animal was stung in like manner, and no carbolic acid was applied, there speedily ensued swelling, redness, tenderness, and fever. The guinea-pig became weak in movement, and refused all food for 24 hours.

The personal experience of those conducting the experiment showed them that the effects of bee-stings upon their own persons could be annulled by carbolic acid. Experiments were next made with some of the venom of a toad. It was found that if this were inoculated into the breast of a sparrow the bird speedily fell, and within a short time died. When, however, the point of inoculation in another sparrow was impregnated with carbolic acid, though there appeared severe signs of suffering, in three hours there was complete recovery. The question which then occurred was—To what were the symptoms of suffering due: to the inoculation, or to the toxic agency of the carbolic acid? The course of the signs after the application of the carbolic acid was as follows:—In two minutes the animal began to stagger, and

* De l'Acide Phénique, &c., p, 162.

would have fallen had its tail not acted as a support. Soon after it fell on its side, and its limbs were agitated for half-an-hour. By degrees the suffering passed away. In a comparative experiment it was seen that precisely the same symptoms occurred when carbolic acid was applied to the unbroken skin of another sparrow; an application of three or four drops over the side of the chest caused death in half-an-hour. It was, therefore, pretty conclusive that the toad venom could be annulled by the carbolic acid, though this itself possessed toxic qualities. Again, as a confirmatory experiment, the toad-venom was mixed with equal parts of carbolic acid previously to inoculation; no symptoms of *malaise* were produced.

Lemaire has also recorded cases of bites from gnats which produced serious symptoms immediately and effectually relieved by the local application of carbolic acid.*

Instances of rapid relief in cases of the stings of wasps are also recorded, and the following important piece of evidence is adduced. M. Sumichrast, an eminent entomological collector, stated that he had in former times been compelled to allow some fine specimens of the *Hymenoptera* to escape, on account of the serious injuries which they inflicted; now, however, thanks to carbolic acid, which he applies immediately, he never objects to brave the dangers of their stings.

M. L. Biard has recorded many instances of dangerous bites from *scorpions* in the human subject, which, treated externally by carbolic acid, recovered with the same rapidity as those of bees and wasps just mentioned.

Carbolic acid has been employed in Australia as a remedy for *snake-bites*. Its mode of use has been both externally to the bitten surface and internally as a medicine. It is considered beneficial, "and perhaps a specific cure." In a case bitten by a tiger-snake of the most venomous kind, "six hours after the boy was bitten there were administered

* De l'Acide Phénique, p. 626.

ten drops of pure acid in brandy-and-water every few minutes. The operator, Dr. Boyd, of Warrnambool, declares that, from a pallid countenance, slow pulse, and semi-comatose condition, the patient rallied to a bright expression, ruddy glow, and quick pulse, and the recovery, though slow, was continuous and certain." This quotation was made from the "Homeward Mail."*

The favourable influence of carbolic acid in snake-bite, however, in other cases and by other observers, is not confirmed. Dr. Fayrer has found that it is powerless in the case of the most venomous snake-poisons of India. Dr. S. Weir Mitchell says that carbolic acid, when mixed with venom and injected into the tissues of a living animal, delays death, and certainly lessens the local symptoms; but probably it effects this only by retarding circulation, and consequently absorption. He adds, "in no internal dose was it of any use to bitten animals."†

From the history of the subject of snake-bite—of remedies vaunted at one time and discarded at another—we must hesitate before accepting the evidence that carbolic acid is a specific for the venom of serpents. There is, however, evidence to show that admixture with carbolic acid is sufficient to annul the effects of some of those venoms secreted by living organisms which are capable of inducing toxic and fatal symptoms upon the animal body.

In considering the possible action of carbolic acid upon the venoms secreted by living animals, the first question which arises is,—What is the nature of the active principles of these venoms? It is a matter of common knowledge that the amount of venom introduced by the inoculation is extremely small, and that it induces its dangerous and fatal results with great rapidity. So it differs from any of the toxic substances, organic or inorganic, with which

* *Vide* British Medical Journal, Sept. 19, 1868, p. 322. See also Dr. John W. Hood, in Medical Times and Gazette, August 6, 1868, p. 170.

† Medical Times and Gazette, Feb. 6, 1869, p. 138.

we are acquainted. Its action obviously is by absorption into the blood. As described by the great dramatist—its effect—

> "Holds such an enmity with blood of man
> That, swift as quicksilver, it courseth through
> The natural gates and alleys of the body;
> And with a sudden vigour it doth posset
> And curd, like aigre droppings into milk
> The thin and wholesome blood." *

The effect of the minute quantity of poison upon the great mass of the blood, was by the ancients and through ages of observation, likened to the phenomena induced by a ferment. Dr. Halford, Professor of Anatomy in the University of Melbourne, describes the results of careful and patient microscopic examination, to show that the blood of an animal drawn shortly after it has been bitten by a venomous snake, contains a quantity of nebulous or granular matter, capable of rapid growth and reproduction. This nebulous matter breaks up into small masses, whence cells foreign to the natural constituents of the blood are evolved. In two hours after the bite such cells may be seen in great numbers; they consist of a delicate cell-wall, with one or more nuclear aggregations in its interior, as well as a bright particle or "macula," which occasionally executes a movement of rotation within the cell. It would appear that the cells increase in number by division of their nuclear aggregations; in twenty-four hours after the bite they seem to have attained maturity and cease to multiply.

As to the relation between the nebulous matter and the inoculable virus there may be two hypotheses. Either the former may be derived directly form the latter, and may by its own multiplication form the foreign cells found in the blood, or it may be an irritant cause superinducing the formation of the cell-elements from the blood itself. The nebulous particles are of such minuteness that they pass readily from the maternal to the fœtal system through the placenta. The mode, then, in which the poison induces

* Shakspeare.

its results, is by the formation of new cells within the living blood at the expense of the nutritive properties of the latter, and by the perversion of those chemical changes necessary to the maintenance of life.* The blood is deficient in fibrine, oxygen, and heat, but has become peopled with a peculiar new growth of cells.

Some evidence concerning the causation of venom-poisoning may be deduced from the results of treatment. One of the oldest-vaunted remedies for snake poisoning was ammonia. It is obvious that though this could be absorbed by the living body with great rapidity, its action could not be so pronounced as if it were injected at once into the torrent of the circulation to mingle with the poisoned blood. Professor Halford conceived the idea of injecting the liquor ammoniæ directly into a vein. The results in animals and in the human subject appear to have been very favourable.†

On the other hand the pathology and the treatment enunciated by Professor Halford do not go uncontested. Dr. Fayrer of Bengal, has failed to find the cell-formations in the blood of the victims of the cobra; and has failed to annul the effects of the poison by ammonia injection.‡

Dr. S. Weir Mitchell, after careful and elaborate investigation, shows that when snake venom comes into contact with minute blood vessels, these latter are weakened so that blood escapes and becomes extravasated. Moreover the coagulating power of the blood is arrested. Thus in the case of snake-venom, "we have a poison that causes bleeding directly, and destroys the natural means of arresting it by putting an end to the coagulating power of the escaping blood." ||

Professor Halford has subsequently considerably modified his views concerning the pathology of snake poisoning. He confirms observations made by Mr. Ralph, that a molecular and leukœmic condition of blood similar to that which

* See British Medical Journal, December 21, 1867, p. 563.

† Lancet, January 30, 1869, p. 168.

‡ Lancet, March 20, 1869, p. 406.

|| Medical Times and Gazette, February 6, 1869, p. 138.

occurs in animals bitten by snakes, obtains in animals poisoned by prussic acid. Probably this condition will be found to arise wherever coagulation of blood after death is prevented.*

The pathology, therefore, cannot be considered as settled, and it is possible that in spite of the very favourable results recorded by Prof. Halford, the treatment may have to join the long list of possible, though uncertain, cures.

The question yet remains, Does the venom of a living animal owe its properties to an organic poisonous principle, or to organised particles possessing vitality derived from the animal secreting them ? If the former, Prof. Halford's pathology might be still correct, and the organic irritant might excite the blood to new intrinsic combinations possessing proliferative powers, which carbolic acid or ammonia could destroy. If the latter, these would be destroyers of the organised particles from the first.

Prof. Halford considers that the activity of venom is due to minute elementary germinal matter suspended in venom. Dr. Mitchell says that nothing like germinal matter exists in the venom.

The viper poison has been described as a neutral† nitrogenous substance, of a gum-like character, *soluble* in cold water, and not coagulated at a boiling heat. The poison of the salamander and the toad has been found by MM. Gratiolet and Cloez to be soluble in alcohol, and to present the general reactions of an alkaloid. Dr. Mitchell has adduced most striking experiments showing that snake-venom possesses no toxic power whatever when administered by the stomach ; whether being albuminoid in its character it is converted by the gastric juice into a harmless peptone, or whether, altered so as to become innocuous, it escapes with the stools, he is unable to say.

There is no evidence of any reproduction of venom in the blood of an inoculated animal. It appears to me from

* See DOBELL'S Reports on Progress of Medicine, 1870, p. 476.

† The fluid cobra-poison has, according to Dr. FAYRER, a slightly acid reaction. Edinburgh Medical Journal, April, 1869, p. 923.

the present state of our knowledge, though the question may be regarded as far from settled, that the probabilities are in favour of the venoms secreted by animals being organic rather than organised poisons. Probably albuminoid in their nature, they are rendered innocuous if introduced into the stomach, but inoculated at once and absorbed into the torrent of the circulation they manifest these effects as any other diffusible toxic agent. Their influence is exerted upon the blood and upon the vaso-motor system.

In any cases in which carbolic acid has exerted a favourable influence, whether employed externally or internally, it has probably been in virtue of its powers as a means of coagulating albumen or of retarding absorption, and not in any sense as a septicide.

CHAPTER XV.

ACTION OF CARBOLIC ACID ON THE POISONS OF INFECTING DISEASES.

Vaccine.—M. Lemaire observed that when he made strictly parallel inoculations, using pure vaccine in the one case, and the same vaccine mingled with carbolic acid in the other, whilst the punctures in the former case resulted in the usual vaccinal phenomena, those in the latter presented not the smallest inflammatory sign. In infants, when immediately after ordinary vaccination, a puncture was touched with carbolic acid, whilst the others were not interfered with, that treated with the agent produced no vaccinal pustule, whilst each of the others passed through its ordinary stages. It had been previously demonstrated by M. Clerc that cauterisation of a vaccinal puncture with potassa fusa five minutes after it had been made failed to annul the effects.

It is well known that carbolic acid has been and is now extensively employed with the avowed object of arresting

in their course the spreading diseases of men and of animals. Its first employment to this end in any really scientific mode was practised and advocated by Mr. Crookes, during the outbreak of the cattle plague, in 1865. Satisfied from the data which we shall presently discuss, that the contagium of cattle-plague existed in solid particles disseminated in the atmosphere, Mr. Crookes caused the air of an infected shed to be drawn through strata of cotton-wool, so as to filter from the former the solid particles which consequently became entangled in the wool. One portion of the cotton-wool was then exposed for half-an-hour to the vapour of carbolic acid. Two healthy calves were then inoculated, the one with the uncharged wool, the other with that subject to the antiseptic vapour; the first calf took the disease and died in a few days, the second remained perfectly well. This experiment is far from conclusive, though it has afforded *primâ facie* evidence that carbolic acid annuls the contagious property of cattle plague as it annuls that of vaccine.

Mr. Crookes then adopted means for investigating the power of carbolic acid over the transmissibility and malignancy of the cattle plague virus. The observations tending to elucidate the question he classes in the following grades of stringency and severity:—The simplest is to endeavour to protect a healthy farm from the invasion of the epidemic. Next in severity is to stop the plague when it has already invaded a farm. A more severe test is to prevent communication from a diseased to a healthy animal when these are in close contact. Lastly, the final problem is to counteract the disease in the organism when its phenomena are already manifest. Mr. Crookes records instances in which complete immunity from disease occurred in farms where carbolic acid vapour was freely diffused through their atmospheres, though the disease raged in the immediate neighbourhood, and they were in the track of the infection. Again, a severe test was adopted by placing together a sick beast and a healthy one, the atmosphere of the shed in which they were having been laden first with sulphurous acid, and afterwards with carbolic acid vapour.

Though there was actual contact between the animals, no symptoms of infection showed themselves for one month: at the end of this time the healthy animal showed signs of the disease in a very mild form, and in a few days recovered. In a second experiment, conducted in a similar manner (actual contact being prevented, however), a healthy bullock contracted the disease on the 9th, and died on the 13th day. In a farm in which the disease was going its virulent course unchecked, a sudden and absolute arrest took place directly after the free use of sulphurous and carbolic acids, though the disease in the immediate neighbourhood continued unabated. Another important test was supplied by the following circumstances:—In a farm existing in the midst of a neighbourhood where the cattle plague is raging the cattle are divided into two lots, 45 being placed in houses treated with sulphurous and carbolic acids, and 28 in open sheds not so treated. The disease is accidentally brought into each lot on the same day by the direct inoculation of the virus. Of the former class only those actually inoculated catch the disease; of the latter, unprotected, the whole are rapidly swept off. Long afterwards, the yet healthy animals, having been turned out in the open, and removed from the protecting influence of the carbolic acid, took the disease and every one died. Mr. Crookes concluded from his data, that when the plague does enter a shed which for some time past has been sufficiently impregnated with sulphurous and carbolic acids, it loses much of its virulence, and is deprived of its infectious character. The severest test of all was next adopted—the injection of carbolic acid into the blood of living animals actually suffering from the cattle plague, with the hope of curing the disease. It should be remembered that in the natural course of the disease it was usual for the animal to show signs of illness on one morning, to be worse on the next, and to die on the third or fourth day. The following are the tabulated results in cases in which carbolic acid was injected into the circulation.

Table showing Results of Injecting Carbolic Acid into the Blood of Animals suffering from the Cattle Plague.

No.	Grains of Carbolic Acid injected.	Temperature before Injection.	2nd Day.	3rd Day.	——
		°F.	°F.		
10	26½	105·4	103·8	Better.	Died on 6th day.
11	52½	103·8	102·8	Better.	Died on 6th day.
12	78¾	104·8	104·4	Better.	Died on 6th day.
14	105	103·7	103·1	Better.	Recovered.

"Taking the whole amount of bloood in each animal at 150 pounds, there were injected into

No. 10, one part carbolic acid in 40,000 of blood.
,, 11 ,, ,, 20,000 ,,
,, 12 ,, ,, 13,300 ,,
,, 14 ,, ,, 10,000 ,,

"It is worth mentioning, incidentally, that in the case of cow No. 14 (which recovered), the proportion of carbolic acid injected into the blood would have been enough to keep from decomposition the whole quantity of that liquid for a considerable time. In Nos. 10, 11, and 12 the proportion of carbolic acid would probably not have been sufficient for that purpose."*

Mr. Crookes's conclusions as to the efficacy of carbolic acid in arresting the spread of cattle plague have been confirmed by observations which have been recently made public.

Mr. Wm. Hope, V.C., in a paper read before the British Association, at Liverpool, 1870, states how he put in practice Mr. Crookes's suggestions. The rinderpest having broken out in a herd of upwards of 260 cows in its virulent form, Mr. Hope undertook the treatment of one-half of the number by the carbolic acid plan. "The result was," says Mr. Hope, "that while every single animal that I did not take charge of either died or was slaughered, I succeeded in

* See Report by Mr. Crookes to Cattle Plague Commissioners.

saving every single animal that I did take charge of."* Dr. E. A. Parkes has expressed his conviction that carbolic acid deserves the foremost place as a means of limiting the spread of infectious diseases. Dr. Parkes performed a disagreeable experiment upon himself: he inhaled, for the purpose of testing their morbid effects, the exhalations from sewers. The first effects were a nasal catarrh, and an irritation of the mucous membrane of the throat; hyper-salivation followed, and subsequently, after an interval of 30 to 50 minutes, nausea. In a few hours occurred chilliness, headache, and fever, lasting from 20 to 24 hours. None of these effects were observed when the sewage matters had been previously treated with a sufficiency of carbolic acid.†

Dr. Wm. Budd, of Bristol, has stated that by the employment of disinfectant agents "the contagion of scarlet fever, of hooping cough, of diphtheria, and of many others of the same family, may be in great degree if not wholly disarmed." There is also, he says, every reason to believe that the contagion of typhus may be thus limited.

If it be granted, as seems to be the lesson of a long experience as well as the commonly employed rule of practice of the present day, that carbolic acid in common with other agents has the power of arresting or limiting the spread of infectious disease, it is necessary to enquire in what mode and in virtue of what property it exerts this power, and this leads necessarily to an investigation as to the nature of those diseases which are known to be contagious or infecting. This subject we will briefly consider.

* Chemical News, October 21, 1870, p. 196.

† Lancet, November 21, 1868.

CHAPTER XVI.

THE ZYMOTIC THEORY.

Common experience tells us that many of the diseases that afflict the animal body are not in-bred within that body, but are communicated to it from without. Just as the ordinary poisons are, by their entrance into the animal economy, capable of causing disturbances of those processes which concur to produce perfect life and health, so certain poisons of disease are capable of inducing an analogous, though not a similar, perturbation; only, in this latter case, the demonstration of the first causes and the various stages of action is more difficult and more complex. The external causes which produce disease are not all material. The physical forces, heat, electricity, &c., are capable, we know, of more or less violent interference with the phenomena of perfect life. Yet there are many diseases which an accumulation of evidence shows us to be due to actual material poisons. Some of these we can actually demonstrate; some we can only infer, though our powers of demonstration are becoming day by day more pronounced. The disease called itch, for example, we can show to be due to a minute animal which can be transmitted from one animal body to another; the various worms which infest the animal body are, by themselves or by their eggs, capable of transmission, and the effect is the disease, with all its train of symptoms, which is associated with their presence. As we advance to the consideration of other diseases which are transmitted, the demonstration becomes more difficult; we cannot always isolate and demonstrate the *materies morbi*. It is not of absolute need, to the support of a proposition that a disease is communicable by material bodies, that we should be able to accomplish this actual demonstration. No one disbelieves in the existence of the air which he breathes because he cannot see its atoms. To prove the proposition, so far as any proposition in Biology can be proved, it is not necessary to demonstrate to the eye the ultimate cause.

A considerable amount of confusion has arisen from the fact that various writers have attached various meanings to the terms *contagion* and *infection*. With some writers these are synonymous, and at the present time they are applied almost indiscriminately, but with others the former is applied to those diseases which are communicable from person to person by actual contact, the latter to those which are transmissible by the intervening media, air or water. It would at the outset appear right that contagion should imply direct contact. When, however, we come practically to apply the term, we find that we are obliged to group dissimilars. Thus, we know that scarlatina is contagious; so, also, are itch and ringworm; and yet these are essentially three different diseases,—the first, a fever arising from a peculiar state of the blood; the second, the effect of a parasitic animal; the third, the result of the growth of a fungus. Of the two last we can isolate and demonstrate the ultimate cause; the microscope shows the itch insect and the vegetable filaments of the *achorion*; the cause of the first is subtle and invisible. The mode in which scarlatina is contagious is not evident to the senses; we see in a moment how contact transfers the germs of itch or ringworm. It is a disadvantage when a single term is applied to diseases so different as these.

Very few diseases are propagated *solely* by the actual contact of a diseased with a healthy person; in most cases intervening mechanical means can convey the disease-inducing causes from the one to the other. Moreover, the term contagion implies contact, and nothing more: in cases such as itch and ringworm, where the essence of the disease is a local irritation, this may be admissible, but in the diseases wherein an essential part of the phenomena is a radical change in the conditions of the system its employment does not seem satisfactory. The word *contagium*, as applied to the poisons of spreading diseases, is also open to this objection—that its mode of operation is indicated as some unexplained catalysis.

The word *infection*, on the other hand, implies a process

of change in the constituents of the body, an inter-penetration of disease elements with healthy structures, as well as a communication of the power of infecting other organisms, and seems more closely to indicate the operation of those spreading diseases which involve the functions of the whole body and effect a change in the economy. It is a matter of extreme difficulty to satisfactorily classify such diseases as we have just mentioned, but an attempt may be made in this mode :—

(1). There are certain diseases, whose poisons are evidently ponderable elements, which can be practically and experimentally transferred, and which, from their comparative grossness, afford facilities for analytical investigation. And yet these are known to infect and to change the conditions of the blood and the general organism. Such are vaccinia, variola, varicella.

(2). In a second class the first causes are traceable, though they are more obscure, through the dejecta of infected organisms; and these influence, in a more pronounced manner than the others, the alimentary tract. Such are diarrhœa, cholera, enteric fever.

(3). Another class of diseases appears to be due to extremely subtle influences, easily wafted by the air, inducing much fever, being especially determined to skin and mucous surfaces, and propagated probably by particles detached from such surfaces. Such are the exanthemata—scarlatina, erysipelas, measles; diphtheria, and various forms of throat inflammation.

(4). Others appear to be due to the transmission or inoculation of certain products derived from the abnormal decomposition of purulent matters, or the accompaniments of the surfaces of wounds. These, once transmitted, excite intense fever and have great powers of re-infection. Such are pyæmia and hospital fever.

(5). In another class, whatever the first causes, common observation shows them to be at the present transmitted only from one human organism to another, to especially influence the blood which is rendered capable of transmitting

the disease, and to have a protracted sojourn in the recipient organism. Such is syphilis.

(6). In another class, propagated by the abnormal products of a human organism, the effects are *chiefly* upon mucous surfaces, whose excretions again transmit the disease. Such are gonorrhœa, purulent ophthalmia.

(7). In a seventh class, though the transmission and reproduction are evident, the causes are obscure. Such are pertussis, parotitis.

(8). There is a class whose transmissibility is not yet admitted, yet experimental evidence seems to prove this possibility. Such are the forms of tubercle.

(9). There is a class of diseases transmissible from the lower animals to man. Such are glanders, hydrophobia.

(10). Lastly, there are diseases transmitted from one to another of the lower animals, which closely follow the phenomena of disease in man, and which afford opportunities of analogical investigation. Such are cattle-plague, sheep-pox, and many others.

From this brief review we can obtain certain distinct impressions concerning infectious disease, and a further examination will fill in the details. First we note that, granted that the poisons producing such diseases are material, the amount of poison necessary to produce all the effects is excessively minute. Of all these, the poison of variola is among the most capable of actual demonstration. Yet, concerning this poison, Dr. Bence Jones says,—"If the minutest particle of substance, a little dried albuminoid substance, in a peculiar chemical state of action, on a lancet or in the dust of the air, is put into the cellular tissue, or is inhaled into the lungs, it passes on to the blood, and through it into every texture. In a few days the chemical actions of oxidation and nutrition throughout the body are altered, and the particle of matter has reproduced itself immeasurably." * Concerning such a poison, peculiar

* Bence Jones, Lectures on Pathology and Therapeutics, p. 228. London: Churchill, 1867.

in that its efficient amount is so minute as to be scarcely conceivable, we have further evidence—(1) that it has a period of latency within the body before manifesting its effects; (2) it exerts a violent influence upon the body, inducing the phenomena of fever; (3) by some means it increases in the body with extreme rapidity and in extraordinary degree; (4) unless the perturbation induced by it is sufficient to destroy the life of the organism which contains it, it is cast off, and the organism is so radically changed that it is no longer susceptible of like changes from a like cause; (5) the poison cast off is capable of inducing the disease, with all its phenomena, in vast numbers of other persons subject to its influence.

With what kind of agent, and with what class of phenomena, can we compare the poison and the series of actions? They have no resemblance with the operation of the inorganic poisons with which we are well acquainted. They have no close resemblance with the actions of the ordinary organic poisons; their potential energy, and especially their reproduction, lift them from this class. With the phenomema of fermentation they have an analogy which cannot fail to be marked.

This analogy has been observed from the earliest days of medicine. Hippocrates taught that fever was due to a poison which entered the blood; that such material poison went through a certain process in the blood, in a certain time, which caused the symptoms of the disease and tended to its own expulsion; that, finally, it was expelled by hæmorrhage, sweat, or discharges, or by pustules, eruptions, or abscesses upon the surface of the body. These attempts at elimination constituted the crises of the fever.

These propositions, variously elaborated, constituted the humoral pathology which lasted for centuries. In later times, the operation of the poisons of infectious disease has been more closely compared with the phenomena of fermentation. The poison of disease is as the leaven; the fever as the molecular disturbance induced by the process of fermentation; the reproduction and increase of the

poison as the communication to the fermenting mass of the properties which belonged to the leaven first added. Such was the doctrine of Liebig, promulgated in 1840. But what, according to this author, was the nature of the substance, whether leaven or disease-poison, which induced in either case such marvellous effects? It was considered to be a material whose molecules were in a state of destroyed equilibrium, of change, of motion: this motion in the act of fermentation was communicated to the fermentescible body, or, in the operation of disease, to the fluids of the body; and such motion might thus be re-communicated indefinitely. It is almost universally considered that the merit of thus illustrating the phenomena of disease by the phenomena of fermentation is due to Liebig; but from what I have been able to elicit, I cannot fail to consider that the doctrine, in almost the precise terms, was enunciated long before the exposition of the illustrious chemist. The Hippocratic view shadows it forth; writings of the earliest part of the eighteenth century definitely express it. Thus Dr. Mead, in 1702, compares the action of the poison of the cobra to a "great fermentation, and working like barme." The venom, he says, may cause disjunction and disunion of the component parts of the blood, and such alterations of fluidity and impulse "from what this liquor had before that its very nature will be changed, or, in the common way of speaking, it will be truly and really *fermented*." * Then concerning fermentation itself, after citing Bellini *de Fermentis*, he adds, "Whatsoever power is sufficient to make a change in this attraction or cohæsion of the parts makes an alteration of the nature of the fluid; that is, as the chymists express it, puts it into a fermentation." † Then, again, when Mead treats of venomous exhalations, there occurs this remarkable passage:—"We are therefore to take notice, that when a fever is communicated by way of infection from one already diseased, this most commonly happens in the latter end of

* A Mechanical Account of Poisons, in several Essays, p. 13.
† *Loc. cit.*, p. 14.

the distemper, that is (as we before discoursed concerning the hydrophobia) when the fermenting blood is throwing off great quantities of its active fermentative particles upon the glands of the most constant and easy secretion; such are those in the surface of the body, and the mouth and stomach. By this means, therefore, the liquid of insensible perspiration and the sweat is impregnated with these Μιάσματα, and thus the ambient air becomes filled with 'em; so that not only, as Bellini argues (De Fibrib, Prop. 27), may some of these effluvia insinuate themselves into the blood of a sound person thro' the pores of the outward skin, but also in inspiration thro' the membrane of the lungs; for he has in another place (De Motu Cordis, Prop. 9) demonstrated how the air or something from it may this way come to be mix'd with the arterial fluid; and thus the like ferment will be raised here as was in the originally distempered subject." *

There seems to be here nothing wanting to the categorical illustration of the series of changes which Liebig subsequently employed. Only the great chemist made one great step in demonstrating that all the bodies which had the property of communicating "motion" to a fermentescible fluid were of one class—they were albuminous, they contained nitrogen.

From whatever source first derived, the analogy of the spreading diseases with the phenomena of fermentation was accepted by the learned of all nations, and these diseases were thereupon classed under one heading which implied this resemblance—they were termed *zymotic*. This term was first employed as it continues now to be by our own far-sighted Registrar General.

The question may occur, "How will the fermentation theory explain the immunity of a patient from subsequent attacks of a disease which he has once experienced?" According to Mr. Simon,† there must be a specific

* *Loc. cit.*, p. 161.

† General Pathology, London, 1850, p. 263.

material within the body, which the specific external poison in its course of action tends to exhaust. Just as an alkaline carbonate, to which an acid is added up to a given point, continues to effervesce, but afterwards refuses to do so; so when the animal system has suffered a change in respect of one of the matters it once contained, it is no more liable to a like change again. "Of this material, whatever it may be, no trace remains in the blood, when the disease has completed its course."* In some cases this ingredient might not be present in the blood; thus would be explained the non-infectibility of some persons. We shall hereafter consider whether this can be explained in another mode. Mr. Simon, then, considered that infectious diseases were due to a material organic poison, capable of converting some constituent of the body into identity with itself; the phenomena were like those chemical actions called catalytic, such as the determination of the union of hydrogen and oxygen by the influence of spongy platinum, the conversion of starch by diastase, or the fermentation of sugar by yeast.

The occurrence of the Cattle Plague of 1865, 1866, and 1867, and the Cholera Epidemic of 1866, afforded a bulk of evidence which strongly supported the *zymotic* theory. Of the particulars of the evidence thus afforded we shall treat hereafter.

Let us enquire first into the relation between the precise phenomena of infectious diseases and the so-called catalytic changes. In the first place, in what sense is there a resemblance with the catalytic action of spongy platinum? In so far as its presence determines new chemical combinations this may obtain; but it does not explain one of the most prominent characters of infecting poisons, their power of reproduction. The spongy platinum does not reproduce itself nor delegate its powers to other matter. Consequently the analogy fails in one of its most essential points. So also does infection differ cardinally from the

* *Loc. cit.*, p. 263.

action of diastase. It is quite true that a small quantity of diastase will convert starch into dextrine, and subsequently into sugar. One part will thus convert 2000 parts according to Persoz and Payen. But it is not true that a fragment from the material thus converted will induce a like change in a new solution of starch; as a particle from an infected organism will propagate infection.

The analogy supposed to subsist between the action of pepsine and that of an infecting poison has been most strongly urged. But here also a like difficulty presents itself. Pepsine is an organic substance which determines the solution of albuminoid solutions with certain acids; but pepsine in this operation does not multiply as a disease-poison multiplies. It is only, therefore, with a certain class of these so-called catalytic changes of diverse characters which have been grouped under the head of FERMENTATIONS that infection presents a close analogy. These are the fermentations in which there occurs reproduction of the ferment. But in these we have seen fit to discard in a certain sense the term "catalysis;" we have considered them to be due to the influence of living agents, and this fact explains their powers of reproduction and renewal. It behoves us to enquire whether in this sense also an analogy obtains between them and infection.

A vague hypothesis that diseases might be propagated by living particles existed from early times. In the 17th century, the Jesuit Athanase Kircher, amidst many fantastic and visionary speculations, enunciated definitely a doctrine that contagious maladies were propagated by animalculæ or living particles differing in kind in different diseases.* Thus the hypothesis of a "*contagium animatum*" is not a new one. It was revived in later times by Sir Henry Holland, in his Essay entitled "The Hypothesis of Insect Life as a Cause of Disease." We now come to this position. We have established a close analogy between the processes of fermentation and infection.

* Scrutinium physico-medicum contagione luis quæ pestis dicitur. Romæ, 1658.

The former we consider to be due to the influence of actually living molecules; as these are capable of inducing the phenomena of the former, there is a *primâ facie* case that they may be capable of inducing the phenomena of the latter. It is necessary, however, to trace in the case of infection the nature, so far as we are able to ascertain it, of the "*primum agens*," and to enquire whether this, the poison of spreading disease, is really composed of matter endowed with life.

CHAPTER XVII.

THE NATURE OF MATERIES MORBI—PARASITIC DISEASES.

The proposition that living beings can be sources of disease in regard to other living beings is in these days established without a doubt. These can be traced in their modes of transmission, and can be shown to be adequate to the production of the phenomena which together constitute the condition of disease. If such could not be proved to occur in a single instance, it would be a serious objection to the reception of the doctrine that transmissible diseases are due to minute living particles; but, inasmuch as it can be demonstrated in a large number of conditions of disease, it must be deemed valuable *prima facie* evidence.

Before the discovery of the *Acarus scabiei* as the cause of itch, precisely similar arguments might have been adduced against any view that this disease depended upon an organised cause, as are now advanced against the theory that the spreading diseases, the causes of which are not yet demonstrable, are due to vitalised material. A brief consideration of actual living organisms as causes of disease is important as bringing forward an amount of analogical evidence, and as showing in what manner living matter

existing as an extrinsic body, comports itself in relation with the living matter which is proper to the recipient organism. The undoubted facts of parasitism show that it is far from exceptional that animals in any rank of the scale of being shall contain within or upon them other living beings. In some cases the influence of such contained living beings is not productive of danger to the containing organism; but in many, though it is the necessity of the life of the parasite, it is destructive to the being infested. This subject presents many paradoxes. The female *Lernæa*, a parasitic crustacean, inhabits the eye or gills of a fish: in like manner the male *Lernæa* lives upon her. He, in turn, is infested with parasitic *Vorticellæ*. "So we find parasites of parasites of parasites."*

> "Great fleas have little fleas and lesser fleas to bite 'em,
> And these again have other fleas, and so *ad infinitum*."

The parasites capable of inducing conditions of disease in living organisms are either animal or vegetable.

I. **Animal Parasites.**—The microscopic researches of the present day leave no doubt whatever, that in every case of parasitism, the parasite or its ova were imported into the living body, and were not evolved in it by any process of spontaneous generation. Yet it must not be forgotten that those who actively supported this theory of Heterogeny declared the contrary.† As an illustration of the progressive acts of life of an organism inducing the irritation of a diseased condition, the formerly cited instance of the *Acarus scabiei* is strictly in point.

The helminthic entozoa also illustrated the same. Exclusive of external parasites, there are forty-one helminthic and other creatures recorded by Dr. Cobbold as infesting the human body.‡ These are all conveyed to the body in food: their extraordinary facilities of propagation are shown by the fact that the egg-bearing organ of a common

* George H. Lewes, Sea-Side Studies.

† Pouchet, Hétérogénie.

‡ Tapeworms and Threadworms, 2nd edition, p. 44.

pork tapeworm contains not less than forty-five thousand eggs. These eggs are capable of a prolonged vitality when they are voided from the containing organism—they are but 1-700th inch in diameter, and the embryo they contain but 1-1250th inch in breadth. The symptoms capable of being induced by these parasites are, besides the usual direct intestinal irritations, blindness, convulsions, epilepsy, irritability of the bladder, spasmodic stricture of the urethra, strabismus, hysteria, and insanity.

It is shown, however, that different animal organisms and different individuals differ greatly in their susceptibility to the evil influences of entozoa. A calf, to which tapeworm was artificially administered by Dr. Cobbold, presented no signs of indisposition, though when it was slaughtered its tissues were found to be full of parasites. Again, a pig which harboured some sixteen millions of *Trichinæ,* exhibited no symptoms of pain or discomfort, though a cat was by a like cause severely affected. In man the distress arising from their presence is extreme. There have been probably in Germany alone not less than 4000 deaths in the human subject from trichinous disease.

Trichinosis affords a good example of the causal relation which may subsist between exotic living matter and the manifestation of disease. Introduced with the food into the human intestine, "the larval *Trichinæ* rapidly arrive at sexual maturity, and the young *filariæ* soon after their escape from the uterus of the mother, commence their migrations by boring in every direction through the surrounding tissues till they arrive at the voluntary muscles. They rarely stop anywhere else. In the muscles they become developed, and ultimately surrounded by a cyst which eventually calcifies."* The trichina disease is characterised by a definite train of symptoms; diarrhœa and abdominal pain from the presence of the larvæ in the intestines; extreme prostration, great pain in the muscles, especially when they are moved, high fever, œdematous effusions,

* BEALE, Microscope in Medicine, 3rd ed., p. 266.

symptoms due to the migrations of the parasite and its presence in the muscular system. Recovery from this stage may be followed by wasting and death from destruction of muscular power. The disease is not invariably fatal. There can be no doubt in case of this disease that the symptoms are directly due to the presence and the vital acts of the parasite.

The influence of different conditions both of parasite and of containing organism in producing different living forms and different disease-effects is seen from many examples. The entozoon derived from the pig produces in the human subject a tænia differing morphologically from that derived from the cow. The tapeworm of the dog or calf conveyed to the human body produces a totally different disease-condition —hydatid-disease. Dr John Harley has found the endemic hæmaturia of the Cape of Good Hope and Natal to be due to an entozoon—*Bilharzia Capensis*. The parasite is found chiefly in the veins of the bladder and mesentery, and in the portal vein, and by its presence causes irritation of kidneys, bladder, and bowels. In animals dying of cattle plague, Dr. Beale demonstrated entozoon-like bodies in the voluntary muscles and in the heart.

Vegetables are also constantly liable to be infested with parasitic animals; the occurrences of the excrescences known as galls, known to be due to the deposition of insect larvæ, are instances on this point. For the latest researches on this subject the reader is referred to Professor Hallier's work.*

This review is sufficient to show that living animal bodies, transmitted by various means to other organisms, by their acts of life and the irritations induced by their presence, are frequent causes of the phenomena of disease.

II. **Vegetable Parasites.**—It is well known that numerous vegetable structures in a living state can exist in or upon the animal body in conditions both of health and disease. It is certain also that in some cases they have a distinct

* Phytopathologie, p. 327: Leipsic, 1868. See also Professor HUXLEY's Address at Leeds; Nature, September 15, 1870, p. 404.

relation with disease-processes. All these parasitic vegetables belong to the class of *Cryptogams;* they are so numerous that a notice of a few of them and of some of their relations only can be here attempted.

The *Achorion Schönleinii* is a fungus consisting of a branching network of fine fibres with receptacles containing and scattering minute spores (see Fig. 29). It grows in the hair-follicles and the neighbouring epithelium, and is associated with the skin disease known as favus.

Tricophyton tonsurans (Fig. 30) consists of very minute, transparent, oval or round cells, found within the hair-bulb near its root. It commences, as Dr. Tilbury Fox has shown, in the upper part of the hair-follicle, and by its development the structure of the hair is altered, its constituents being torn asunder.

The *Tricophyton sporuloides* of Plica Polonica, and *Microsporon mentagrophytes,* differ from the latter in very slight particulars. *Microsporon furfur* (Fig. 31), the wavy mycelium of which with its clusters of spores invades the middle portion of the epidermis, constitutes the lesion of *Pityriasis versicolor.*

Chionyphe Carteri is a branching fungus resembling *Aspergillus,* with large globular expansions containing oval nucleated spores (see Fig. 32).

The question of the relation of these organisms, the fungoid nature of which cannot in the present day be disputed, with the several diseases which they accompany, is of the highest importance. Modern observers have shown that by transplantation of the disease-products, the skin-disease can be transferred from one individual to another. Remak and Hughes Bennett, by inoculating with favus-crusts, reproduced the disease and the fungus; Richter inoculated rabbits with a like result. Dr. McCall Anderson has adduced cases to show that such skin diseases are capable of transmission from dogs and cats to man. Gerlach and Salisbury have also instanced examples of such contagion from the lower animals. Ziemssen inoculated

his own chin by rubbing it with diseased hairs from a case of *Sycosis*: the result was the development and growth of the fungi, and the occurrence of the disease upon himself. An instance has lately been brought before the Clinical Society by Dr. Tilbury Fox, of the communication of a skin disease from a pony to seven men of the Royal Veterinary College, who had come into contact with it. The hair bulbs and epidermis of the pony were crowded with *Tricophyton*, and the skin-lesions of the men presented abundant fungus-elements. Tilbury Fox has observed the splitting-up of a hair containing spores by the germination of the latter when the hair had been removed from the body. The diseases are known to be occasionally propagated without actual contact. Bazin and Lemaire have discovered the spores of the *Achorion* in the air of a hospital ward. There can be, from the foregoing and many other data, little room for doubt that the fungi observed in the different forms of skin disease are the direct causes of the symptoms induced.

Moreover, fungoid organisms are found on the mucous membranes and in the interior of the living body. Amongst such is the *Oïdium albicans* (Robin), first described in 1842 by Gruby (see Fig. 33). This constitutes the white aphthous patches of the thrush of ill-nourished infants. It is also sometimes developed in the mouth and pharynx of adults in the course of wasting diseases. The spores and filaments sprout among and within the epithelial cells. The fungus can be transferred from those affected with it to healthy persons with the production of its consequent irritation; wherever it is present the mucous secretion is acid.

It is well known how commonly the occurrence of the *Oïdium* in infants is associated with the occurrence of diarrhœa, and how that when the irritation consequent thereupon is subdued the diarrhœa ceases. It has, I believe, never, except by myself, been suggested that in some of the epidemics of diarrhœa affecting adults a similar cause may have been at work, though our means of detecting it

have not been sufficient. Such irritating causes might be too minute to escape a superficial observation, or might exist in the alimentary canal out of the range of vision. I have frequently observed in children that when diarrhœa has been the only ostensible complaint, there has been a history of the occurrence of white patches on the tongue or palate, which have passed away, or there are traces indicating their recent occurrence. The following views, which I brought forward in 1867,* may have some interest here.

On August 12th, 1867, I was hurriedly called to the servant of a neighbour of mine, who was supposed to be suffering from cholera. There had been slight diarrhœa, followed by signs of extreme prostration, pallor, and coldness. A sense of great oppression was referred to the epigastrium. Fortunately the diarrhœa did not persist, and, though the prostration signs were long persistent, the patient recovered in about a week. On the 16th, *i. e.*, four days after the occurrence of this case, I was called to a patient who lived in a house situated exactly at the back of that in which the first case occurred. This patient had suffered from veritable Asiatic cholera in a former epidemic, and she described her symptoms as exactly those which she suffered from before. The diarrhœa, however, in this case did not persist, and the patient recovered. On the 23rd, I was sent for to see an old lady in the immediate neighbourhood, who also was suffering from symptoms of severe and uncontrollable diarrhœa. Her case was most peculiar, for, on my second visit to her, I discovered, both on the dorsum of the tongue and on the tonsils, *distinct patches of Oïdium.* Under the influence of sulphite of soda her symptoms steadily declined in severity, though not before the condition of the mouth had become a severe local lesion, impeding deglutition, and, ultimately, peeling off and leaving a sore surface. The questions which now arose in my mind were these—Has the occurrence of *Oïdium* any causative relation with this case? and have the other cases which have occurred in the

* "The Nature of the Cholera-Poison," Medical Press and Circular, Nov. 6, 1867.

neighbourhood any correlation therewith? Of course I do not pretend to give an answer in the affirmative to either query, though I cannot help thinking that the circumstances suggest it, particularly as further evidence is forthcoming. Four doors from the last-mentioned case I had been attending a case of scarlatina: on August 27th I was hurriedly summoned to the house, to find two children (who had shown early signs of the last-mentioned disease) seized with violent purging, and signs of almost impending collapse. Both were cold, with blue lips, and marble-like surface; both suffered cramps and excessive diarrhœa, the discharges being fluid and flocculent, and almost destitute of bile. They were certainly in the most critical condition, though they ultimately recovered. At the same time I attended a servant living a few streets off, who suffered from almost identical symptoms; her attack commenced on the 24th. Circumstances of time, place, and similarity of symptoms, show the great probability of an intimate relation subsisting between these cases. The most interesting question, however, is—"Whether the *Oïdium* which was evident in one case had any causal relation either with that individual case or with the other cases?" Certainly nothing of the kind was discovered in the others; neither was it in this case until the diarrhœa had for some time persisted. We well know the relation between the occurrence of thrush in children and diarrhœa. Is it not possible that these cases, which showed so many signs in common, which manifested such intimate relation of time, place, and circumstance, might have some cause in common? And is it not at least possible, inasmuch as a cardinal sign in one case was the occurrence and rapid development of the *Oïdium albicans*, that the spores of this or some such fungoid growth might have a causal relation with each and all the cases?

I gave these observations merely as an interesting speculation; but I believe that the subject is capable of affording instruction by further investigation.

M. Parrot has shown conclusively that the spores of *Oïdium* can germinate in the stomach. They give rise to

minute elevations of the mucous membrane: microscopic examination of these elevations shows myriads of sporules with interlacing filaments, the latter traversing the glandular layer, and sometimes penetrating into the submucous tissue. M. Parrot has not found the *Oïdium* in the alimentary canal below the stomach, but has observed it in a deposit in the apex of the lung of a child.*

Sarcina ventriculi (Goodsir).—A peculiar, but now well-known, fungus, appearing in bundles of superimposed cubes, is found chiefly in the vomited matters of fermentive dyspepsia. Frequently it is accompanied by *Torulæ*, resembling those of ordinary yeast. It has been found, however, in many parts of the human body, and in the excretions; in the urine, the fœces, the ventricles of the brain, in abscesses and cavities of the lung, in the fluid of hydrocele, in gangrenous intestine, in the alimentary canal of several animals, and, as Dr. Tilbury Fox has shown, in some skin diseases.

Leptothrix (Figs. 19 and 34).—A fungoid organism, consisting of exceedingly fine hair-like bodies, has been found in the mouth, the stomach, intestines, uterus, and on the female genital organs. The filaments adhere to, or grow from, the cells of Epithelium; they are found only on surfaces to which air has access, and they are, for the most part, not associated with conditions of disease, though vaginal ulceration is, according to Mayer, occasionally excited by their presence.†

Penicillium (Fig. 17) has been found in vomit, and in the contents of the intestines.

Aspergilli (Figs. 26, 27) have been found in the external meatus of the ear, and in the lung, but they have not been shown to have any connection with the manifestation of disease.

Bacteria (Figs. 1, 3, 4, 35), or the minutest of vegetable germs, according to Dr. Beale, occur in every part of the body of man and animals, at all ages, and in conditions

* "Du muguet gastrique et de quelques autres localisations de ces parasites," Arch. de Physiol. 1869.

† Monatsch. f. Geburtsk., July, 1862.

both of health and disease. "The higher life is, I think," says Dr. Beale, "everywhere inter-penetrated, as it were, by the lowest life. Probably there is not a tissue in which these germs are not, nor is the blood of man free from them. They are found not only in the interstices of tissues, but they invade the elementary parts themselves. Multitudes infest the old epithelial cells of many of the internal surfaces, and grow and flourish in the very substance of the formed material of the cell itself. But the living germinal matter of the tissues and organs is probably perfectly free from vegetable germs. Some are, however, not uncommonly met with on the full surface of the germinal matter when its death and conversion into formed material are taking place."* Dr. Beale believes that, under normal conditions of the higher organism, these vegetable germs are dormant and passive, but spring into activity when the normal condition departs. Millions of bacteria are always present on the dorsum of the tongue and in the alimentary canal, but they remain passive unless some derangement in digestion prevents normal assimilation. In infants such derangement causes milk to remain in the intestines—a source of irritation, and serving only for the nutrition of countless bacteria. Bacteria are found in the circulating blood. "In cases in which these organisms have been discovered actively multiplying in the blood, that fluid must have undergone serious changes, which have rendered it unfit for the nutrition of the body."†

Parasitic Fungi in the Lower Animals.—There is evidence that a very large proportion of the diseases of the lower animals is accompanied by the occurrence of fungoid organisms. The fungi which are associated with diseases of the skin in man occur in like diseases upon animals. Instances of the propagation of such diseases from animals to men have been already quoted. Conversely, M. Jacquetant has asserted that he has traced the spread of favus to cats who were played with by children in the skin-ward of a

* Disease Germs, p. 65.

† Beale, *loc. cit.*, p. 68.

hospital.* M. St. Cyr has studied closely the occurrence of favus in cats, dogs, and mice, and shown all the phenomena to be exactly correlative with those of the disease as it appears in man. Moreover, he sowed the *Achorion Schonleinii* upon a blistered surface of the skin of cats and dogs, producing the disease. M. St. Cyr is led to believe, seeing the frequency of the occurrence of this skin disease in domestic pets, that these play an important part, which has hitherto been overlooked, in the transmission of the disease to the human subject.† Parasitic fungi play a still more important part in relation to the diseases of animals. It is proved that, in some cases at least, they are capable of inducing serious and fatal lesions. An illustration of this is found in the pébrine—the disease which, in epidemic form, has frequently attacked silk-worms, and which has produced such a fatality among those insects as to have made a grave impression upon the commerce dependent on their cultivation. The financial loss to the silk trade of France, *from this cause alone*, has been as much as between *two and three million pounds sterling per annum*. A close investigation has shown this silk-worm disease to be due to the ravages of a fungus, which is inoculable from one insect to another, which invades all the tissues, and kills the silk-worm, reducing it to a mere mass of fungoid vegetation. The producing cause of the disease appears, from the various researches, not to have been identical in every epidemic. The disease, when it was first investigated, was traced to a fungus called the *Botrytis Bassiana*. In later years the disease, as investigated by Lebert and Pasteur, has been shown to be due to minute corpuscles existing in the blood, and in every tissue of the body, and even into the rudimentary eggs existing in the body of the female moth.‡ A destructive disease, very similar to the foregoing, has

* Essai sur le Favus, 1867.

† ST. CYR, Annales de Dermatol. et de Syphilis, 1869.

‡ Prof. TYNDALL, "Pasteur's Researches on the Diseases of Silk-worms," Nature, July 7, 1870. Cf. Prof. HUXLEY'S Inaugural Address to the British Association, 1870; Nature, September 15, 1870.

been shown to attack the common house fly, the obnoxious fungus being the *Empusa Muscæ*. The evidence in these cases, it appears to me, cannot be clearer of a causative relation subsisting between the fungus-cause, the disease, and the fatality. In other cases the relation, although there is much evidence of causality, is more obscure.

In the *malignant pustule* occurring in cattle—the anthracic disease—the blood is possessed of highly malignant qualities. Injected into a sound animal it rapidly induces the train of symptoms of the original disease—the mass of the blood becomes black and fluid, the spleen engorged and presenting extravasated patches, the veins turgid, and the animal dies. Sometimes putrefaction sets in before death, always it occurs promptly afterwards. Upon what condition of the blood does this infecting property depend? M. Davaine has asserted that it is due to the presence in the blood of minute bodies resembling bacteria, but motionless. He terms these *Bacteridia*. The disease of the cattle is capable of inducing malignant pustule in man. In such cases *Bacteridia* are found in the blood, as in the disease in animals, and the pustules themselves are little else than congeries of the like microscopic cellules. The pustules and the blood of the human subject thus infected have been proved again to communicate the disease to the lower animals. But the evidence of causation is incomplete. It may yet be doubted whether it is to the *Bacteridia* alone that the infective quality of the blood is due. MM. Coze and Feltz have made an elaborate series of experiments on the communication of infection to animals. When fluids in a putrid state are injected into the blood of animals high fever follows, and after a certain time death. The blood is altered, its oxygen is deficient, its carbonic acid in excess, and it contains numerous bacteria of comparatively large dimensions. It would appear that a commencing putrefactive change occurs in the blood during life, which is rapidly completed after death. In like manner, blood derived from patients suffering from typhoid fever or from variola will induce similar phenomena in animals to that induced by putrescent

material. It is said that the severity of the symptoms and the fatality are directly in proportion with the number and activity of the bacteria discovered.

M. Davaine has made the important observation that the *Bacteridia* die after putrefaction has continued to a certain stage, and that then they are no longer capable (nor the fluids in which they exist) of communicating anthracic disease. One of the factors, therefore, of infection is a certain stage of development of the morbific material. This will have a great influence, as we shall hereafter see, on the question of the causation of cholera. The views of Davaine have been substantially confirmed in America by Dr. Stiles, who found that in the Texas Cattle Disease the blood contained multitudes of multiplying vegetable germs.* On the other hand, Leplat and Jaillard have recorded experiments to show that though injection of putrid blood is productive of disease and death in animals, injection of putrid vegetable infusions, which also contain fungoid organisms, is innocuous. Again, M. Bouley† denies the causal relation of bacteria in anthracic diseases—inoculation of blood in which no bacteria were demonstrated communicated the disease, and in some ruminants dead of the disease no bacteria could be found. Drs. Billings and Curtis, in their Report on the Diseases of Cattle in the United States, arrive at similar conclusions. They state as a deduction from culture-experiments, that in healthy as well as in diseased animals fungus germs capable of development exist in the blood, and that "in many animals, whether healthy or diseased, there are no fungus germs in the blood."‡ This conclusion, however, is incautiously drawn, for the experimenters ought to have added the words, "in the particular portions of blood made the subject of the experiments." The most important observations in this matter are those of Professor Beale before alluded to, who shows by actual demonstration

* Third Annual Report of Metropolitan Board of Health of State of New York; Brit. and For. Med. Chir. Review, April, 1871, p. 310.

† Comptes Rendus, January 11, 1869.

‡ American Journal of the Medical Sciences, October, 1870, p. 527.

that the normal blood and the normal tissues contain bacteria in abundance. It follows, therefore, either that bacteria exert no morbific influence, or if they do exert such influence they must be endowed with qualities which observation of their form and structure does not indicate. We shall return to this subject shortly.

Fungi in Diseases of Plants.—It is a well ascertained fact that parasitic fungi have an important relation with conditions of disease in vegetables. The existence of ergot in grain has been shown to be due to a parasitic fungus. The rust of wheat is caused by the ravages of *Puccinia graminis*. *Botrytis infestans* (De Bary) occasions the potato-disease. *Oïdium*, in all probability, induces the disease which attacks the vine.*

Correlations of Parasitic Fungi.—Morphology.—From the various names applied to the fungoid organisms which have been thus shown to exist as parasites in or upon the living body, an aspect of great complexity is given to their relations among themselves, and in regard to the systemic conditions accompanying their presence. The question would, however, be rendered much more simple if it could be shown that a bond of union exists between the various fungi, and that they can be traced to a few aboriginal forms. It was believed by Hebra that all the forms of parasitic skin disease known as *Tinea* could be produced by one and the same fungus. Dr. Tilbury Fox has considered that the fungi found on man are developments from a single stock. Given, then, a single particle of living vegetable protoplasm, its effects and its forms would differ according to the conditions in which it might be placed, just as we have seen it to differ in forms and effects in the varieties of fermentation. We will consider the various organisms in detail :—

1. *Bacteria.*—It is unfortunate that this term should have had a loose application ; it has been applied as well to the motile particles seen at the same time with vibrios in liquids undergoing putrefaction as to the motionless particles, which

* For an exhaustive account of this subject the reader is referred to HALLIER'S work, "Phytopathologie."

are mere fragments of vegetable protoplasm capable of development into higher forms. It is most probable that a broad distinction lies between them, though there cannot but exist the fallacy that a *Bacterium* dead and motionless may from observation alone be taken for a fungoid particle.

We shall consider here as bacteria only the moving particles which are associated with vibrios. The first thing to be noticed is, that these motile bacteria are found amongst every particle of a fluid, not in one situation more than another. They can, as Pasteur has shown, live in the absence of any free oxygen. I have seen them in myriads where, owing to the presence of a poison in the air supplied to a putrescible solution, not a trace of a fungoid organism could be detected. No one has ever traced these motile bacteria as resulting in a fungoid organism. These occur in the fluids obtained from the alimentary canal of animals, and in any situation wherein putrefactive changes occur; but there is no evidence that they have any causal relation with disease.

Bacteridia, so called by Davaine, are motionless. Except in form and in comparative minuteness, these have no relations with the motile vibrios and bacteria. These may be regarded as mere particles of protoplasm whence fungoid organisms orginate. Culture-observations undertaken as well by Hallier as by those whose conclusions differ widely from his, agree in showing that the animal organism contains within it organised material capable of development into vegetable forms. Observation shows that the existence of such vegetable protoplasm in those simple forms capable of fission or multiplication, but not progressing to higher metamorphosis, is simply dependent on the conditions in which it is placed. Beneath the surface of fluids, conditions for the higher development of these germs do not obtain—reproduction of their like is the sum of their existence. It is observed that, according to the nature of the fluid in which they float, their form and their powers of proliferation vary. Usually nitrogenous bodies afford them the most suitable pabulum. The reason, therefore, of the appearance of bacteria-like

particles in the blood, and not of organisms more decidedly fungoid in their physical appearance, is that in the blood, apart from atmospheric influence, there are no suitable conditions for their higher development. The motionless bacteria-like bodies in the blood are the *Micrococci* of Hallier, and are analogous to, if not identical with, those which we have seen to assume different forms in the different varieties of true fermentation.

Leptothrix.—The minute masses of vegetable protoplasm, when they approach the aërial surface of any fluid, tend to aggregate in chains. The existence of the *Leptothrix buccalis* is due to the fact that the air in this situation permits of the growth of the bacteroid particles in this form. *Leptothrix* is but a form of ordinary mildew: it may be observed when placed under suitable conditions to grow into *Penicillium.*

Oïdium.—When the fluid at the surface of which fungoid growth takes place is acid, the cells tend to elongate, and form articulated fibres instead of bead-like bodies. This is what is known as *Oïdium.* But the form of the fibre-cells constituting the *Oïdium* varies according to the chemical constitution of the (acid) liquid.

The *Achorion Schönleinii*, according to Hallier, is nothing but the *Oïdium* form of the universally-spread *Penicillium crustaceum.* The two formations are by cultivation convertible. Hallier has shown the *Tricophyton tonsurans* to differ considerably from this—by cultivation it yields not *Penicillium* but *Aspergillus. Microsporon* is merely the minute individual cell which by aggregation constitutes *Tricophyton.*

Penicillium.—The original minute cells (*Micrococci*) having aggregated at the surface of a fluid, and having, when growing upon the surface in contact with the air become elongated as *Oïdium*, proceed to branch and ramify (*Mycelium*), and, the stems reaching sufficiently into the atmosphere, to bear fruit in the form of spores attached to the sides of the straight or forked terminals of the stem. It is growth in the air which determines the form, *Penicillium.*

Aspergillus appears to be higher grade of fungus, and differs from *Penicillium* in its fructification, being in a globular form, and its spores usually of greater size.

Sarcina is a variety of fungoid organism, the relation of which to other forms is very obscure. It is not shown to be the cause of any disease process, unless it be, like *Torula*, an agent of saccharine fermentation. It is seen to accompany fermentive dyspepsia, for it is found in the matters vomited. It is found, however, in very various situations, and in conditions wherein fungoid manifestations are obscure and infrequent. Dr. Bastian found it in his vacuum experiments.

Mode in which Fungoid Organisms enter the Living Body.—It is obvious that there are three means of transport whereby fungi or their germs can be transferred to the living body—(*a*) by solid or liquid ingesta; (*b*) by the air; (*c*) by any material which can directly carry these elements from place to place. Our knowledge that many entozoa can thus penetrate into the organism renders it easy to realise how fungus-elements so much more minute can gain access. So long as it was considered that the "spore" of a fungus of definite character and comparatively large dimensions was the sole origin of the fungus and the analogue of a single seed, it was more difficult to explain its penetration; but now that there is no doubt that the fragments of protoplasm whence a fungus can be evolved are of extreme minuteness, this difficulty is removed. Such minute particles can become insinuated between epidermic or epithelial scales, and where they find conditions suitable for germination, can grow and proliferate in the forms which those conditions determine.

Relations of Fungi as Causes of Disease.—We have seen that in some diseases which have been enumerated the evidence leaves no room for doubt that fungoid organisms are the direct causes of diseased conditions. We have considered, moreover, that the forms in which they are met with are not the result of a multiplicity of varieties of fungi, but that one or two well-known varieties are capable under different conditions of presenting the various aspects observed. It follows that for the production of the condition of the disease there must be not only the presence of the

fungus-cause, but also a certain receptivity of the subject-organism. This is illustrated by the fact, that in families where an undoubted parasitic disease attacks some of the members, others sometimes, for no known reason, escape. So, also, in the parasitic diseases of animals and plants some are unaffected ; as in case of the potato-disease some of the tubers are found healthy.

Dr. Tilbury Fox has proposed the generic term, *Tinea*, to designate the group of vegetable parasitic diseases. The following table has been compiled from his data, with the addition of the correlations arrived at by Professor Hallier from his culture-experiments :—*

Tinea favosa,	*Syn.*	Favus,	Fungus.	Achorion Schönleinii,	Oïdium	of	Penicillium.
„ tonsurans,	„	Herpes tonsurans,	„	Tricophyton tonsurans,	„	„	Aspergillus.
„ circinata,	„	Herpes circinatus,	„	„ „	„	„	„
„ decalvans,	„	Area,	„	Microsporon Audouini,	Micrococcus	„	„
„ sycosis,	„	Mentagra,	„	„ mentagrophytes,	„	„	„
„ versicolor,	„	Chloasma,	„	„ furfur,	„	„	„
„ tarsi,	„	Ophthalmia tarsi,	„	Tricophyton tonsurans,	Oïdium	„	„
„ Polonica,	„	Plica Polonica	„	„ sporuloides,	„	„	„

We may thus understand the appearance and the phenomena of the thrush : fungoid particles, capable of inducing it, are constantly entering the body in the air or in the food ; in normal conditions of the organism, however, there is no tendency for their conversion into deleterious growths : let the mucous surface present an acid reaction, and a soil at once exists whereupon the fungus-germs develope into *Oïdium*, and there react as causes of irritation to the system that contains them.

We are now in a position to review the ground on which we stand in reference to the zymotic theory of disease. We have considered that all *true fermentations*, that is to say, all fermentations accompanied by reproduction of the ferment, are due to the influence of living forms. We have seen a strong resemblance to subsist between the general phenomena of fermentations and those of spreading diseases. Many spreading diseases are shown to be due to living

* Cf. BEALE, Microscope in Medicine, p. 277.

bodies, animal or vegetable. In many others the coexistence of organised forms with disease processes is made out, but the evidence of causation is not complete. Are the diseases themselves "*propter hoc*" as well as "*post hoc?*" We have seen that in the blood of those diseases in which there is evidence of the relation of coexistence, the particles supposed to be the true causes occur in an extremely rudimentary state. The microscope can demonstrate no essential difference between them. In what ways, therefore, can their "specific" effects be explained? Two theories present themselves. Either the "*materies morbi*" are distinct morphological forms, the characters of which in their rudimentary or germ-conditions the microscope is unable to demonstrate; or else the organised molecules, independently of their morphological conditions, are endowed with specific properties.

We have arrived at such a stage that we may consider our *primâ facie* case, that spreading disease may be due to organised material strengthened by a considerable amount of evidence; but before adopting it as a generalisation, we have to enquire concerning the infectious diseases, the causes of which are wrapped in a greater obscurity than those which we have adduced. We must consider whether we have analytical evidence from the examination of the products which we know to be causes of disease, and whether the theory of living matter, as the cause of all infectious disease, can adequately explain the various phenomena.

CHAPTER XVIII.

THE NATURE OF MATERIES MORBI—INFECTIOUS DISEASES.

It is agreed on all sides that the causes which induce the diseases which we have considered as infectious are material poisons. There is at the present time, however, con-

siderable difference of opinion as to the nature of these poisons. On this point there appear to be three well-marked theories.

According to the *first*, the poisons are organic substances which produce their effects by their physical properties alone.

According to the *second*, the poison is not merely organic but organised, and is derived from the living matter of a previously-existing organism.

According to the *third*, the poisons are living germs entirely derived from fungoid organisms.

The last two theories agree in so far as they attribute the agencies which induce infectious disease to a common cause, living matter. The first point, therefore, to consider, is whether the evidence tends to show that such agencies are living or not-living. Putting, for the present, aside the considerations which have established the *primâ facie* case that spreading disease may be due to living matter, we will next enquire into the analytical evidence. What is the nature of infecting material, in so far as we are able to ascertain it by experimental enquiry?

In the case of vaccine (which may fairly be taken as an example of an infecting poison, seeing that it can in extremely minute quantity produce when inoculated into the living body a definite series of systemic changes, resulting in an altered condition of the body, whereby the organism is rendered insusceptible of the influence of some morbid poisons, identical with or closely resembling itself, as well as in a reproduction of the infecting material), the experiments of Chauveau, confirmed by those of Sanderson, leave no room for doubt that the effective element is a *solid*. The infecting qualities reside not in the liquid portions of vaccine lymph, but in the solid particles which do not diffuse in water.*

* For a full account of the Diffusion Experiments, see CHAUVEAU, Comptes Rendus, 1868, 1869. For an excellent summary see the Report by M. VILLEMIN, in DOBELL'S Reports on the Progress of Practical and Scientific Medicine. London: Longmans, 1869, p. 131 *et seq.*

But the demonstration is not confined to vaccine infection. Chauveau has shown that the poison of small-pox operates in a precisely identical manner. Its liquid elements are perfectly incapable of transmitting infection, whilst its insoluble portions are efficient in inducing variola. The same is true of glanders and of sheep-pox, diseases differing widely from each other and from the foregoing in their intrinsic characters, yet all eminently infectious. Sanderson, by another mode of diffusion, found that the infective property of the blood in cattle plague existed in the material which would not diffuse through parchment paper, not in the liquid diffusate, which was perfectly innocuous.

Let us briefly enquire as to the teaching of these results obtained by purely physical investigation, in regard to the phenomena of infectious diseases. It can scarcely be doubted that such diseases must be due to causes which are in their general characters similar, and that those instances which have been already adduced may fairly be taken as types of the whole class. The elements of infection, then, in these diseases, are solid particles of extreme minuteness. Insoluble as they are proved to be, the efficient vaccine particles readily pass through the finest filter-paper. Such minute particles could readily be conveyed (as experience shows to be the case in small-pox, &c.), by the air or by any physical intermedia; and Chauveau has practically demonstrated that vaccine and the sheep-pox poison, in the form of fine powder, will communicate the respective diseases, whether they be inhaled into the lungs or absorbed by the gastro-intestinal tract of an animal. These facts show the pathways by which infectious diseases are disseminated. Furthermore, the investigation demonstrates one great reason of the apparent paradox of the partial distribution of such diseases, the escape of some individuals and the infection of others, when all are, to all seeming, subject to identical influences. When vaccinations were practised by means of the point of a lancet from lymph mingled with water, some wholly failed, whilst

others, even when the dilution was as great as 1 part in 150, were attended with exactly the same phenomena in no way less pronounced than when undiluted vaccine was employed. The explanation is easy—in the negative cases the lancet-point chanced to take up fluid alone, in the positive the solid elements became attached to it. It was not the fact of dilution which impoverished the poison, for if the diluted vaccine itself were injected in bulk, all the symptoms of infection resulted; nor was the efficiency of the minutest solid particle impaired by such dilution. The facts, therefore, of the partial distribution of disease, are the direct consequence of the poisons being solid; the chances of infection are precisely in the ratio of the number of infecting particles contained in a given medium. As Dr. Sanderson happily expresses it in his most valuable Report:*—" The question is frequently asked, how does it happen that a person may be exposed every day for many months to the contagion of typhus with immunity, and yet be eventually attacked without any change whatever being made either in his own condition or in that of the infected media by which he is surrounded? If contagium were gaseous the fact would be inexplicable—as inexplicable, indeed, as the assertions of the homœopathists. Assuming it to be insoluble and particulate, the question of mediate contagion must, like that of direct contagion, be one of chance. Just as in the case of inoculation, the effect of dilution shows itself exclusively in the proportion of failures to the total number of insertions, so in exposure to infected air the effect of distribution of the poison through a large volume of air shows itself in the proportion of escapes to the total number of exposures which the individual passes through. And just as in the former instance, the last inoculation of a series is just as likely to be the one by which a particle of contagium is introduced as the first, so in mediate contagion the last exposure is just as

* Introductory Report by Dr. Burdon Sanderson, On the Intimate Pathology of Contagion. Twelfth Report of the Medical Officer of the Privy Council.

likely to be the effectual one as the first. To put the case more familiarly: a railway guard who has made the same journey every day for the last 10 years, is just as likely to meet with an accident to-day as he was the first day that he was on duty, because the coincidence of circumstances which lead to an accident is just as probable on one day as on another. So in like manner a person of given susceptibility who has lived for a year in an infected atmosphere is subject to the same degree of risk on the last day as on the first day of his exposure."*

We shall see hereafter that there are other causes also for the immunity of certain persons, even when the facts of inoculation have been established. The researches, however, establishing the common relation of infecting poisons —that they are solid particles—have enunciated certain conclusions as to their intrinsic variations. Diseases are perfectly well known to differ in their infectious qualities; an equal quantity of the infecting poisons of different diseases manifests infecting powers widely differing in degree. Sheep-pox is extremely infectious. Chauveau determined that its poison is thirty times more active than vaccine; in other words, its efficient particles being more minute, a given quantity contains thirty times as many in the one case as in the other. Furthermore, the infecting particles in different diseases differ in regard to the sites in which they are found. In the cattle plague all the fluids of the body become capable of inducing infection; in sheep-pox, vaccine, &c., the activity principally resides in the cast-off products.

The conclusion that the infecting poisons are solid, insoluble, and indiffusible colloids, is one that can scarcely fail to be adopted. We may enquire now into the results of this conclusion on the theories of infection.

In the first place, the fact alone that the poison is a solid, puts aside the notion that it can operate in any ordinary chemical or physical manner. Such particles absorbed into

* Report, p. 241.

the blood would not diffuse throughout it but merely circulate in it. We have to search for an explanation farther than the analogies offered by the ordinary operations of organic matter. An attempt has been made to elucidate the mode of action by reference to the mode of operation of analogous colloid bodies, which for want of a better knowledge of the influence is termed catalysis. We may take as a type of such action the solution of albuminous substances through the agency of pepsine, for this has been adduced as an illustration of the mode of action of infecting poisons.* The element of the gastric juice which confers upon it its power of rendering the albuminous solids of food soluble and diffusible (in the presence of a free acid) is itself insoluble and indiffusible. Diffusion through a membrane demonstrates that the fluid diffusate possesses no digestive power whatever, whilst the remainder, deprived of all that is soluble, possesses this property abundantly. Dr. Sanderson says, "Pepsine is but one of a group of substances which perform what in a general sense may be called zymotic functions in the animal economy, all of which have this property in common—that they induce important chemical changes in other kinds of substances, without themselves participating in the transformations they effect. This faculty of causing chemical changes in other contiguous matter is all that is implied when the process of infection is compared to a zymosis." We will consider in how far there is a resemblance between infection and pepsine action (which we may fairly take as a type of catalysis), and in what respects there is a divergence in the modes of action. These resemble each other in their first causes, in that both are insoluble colloidal particles; the analogy subsists in their mode of action, but only to a limited extent. The operation of both is obscure, it is true; but surely the fact of this obscurity is in no sense to be considered a scientific analogy. Unlike the disease-poison, pepsine is by itself powerless to induce the change of physical state in

* Dr. SANDERSON'S Report, *loc. cit.*

albuminous matters—it has no power of digestion unless hydrochloric or lactic acids be present. Its function, therefore, is not immediate, but intermediate. Moreover, there is a wide difference in the *degree* of action in the two cases. Lehmann estimated that 100 grms. of fresh gastric juice (containing from 5 to 17 parts of pepsine per 1000 according to Vogel), were required to dissolve 3 to 5 grms. of coagulated albumen; Schmidt considered that 100 grms. accomplished the solution of only 2 or 3 grms. On the other hand, an invisible quantity of disease-poison is capable of inducing upon the mass of tissues of a living mammal the violent perturbations of disease. A lancet, the point of which has been dipped in a dilution of one part of vaccine fluid in 150 parts of water, and which necessarily then contained an almost infinitesimal quantity of the poison, has communicated the perfect phenomena of vaccine disease; and in sheep-pox a puncture inoculating a dilution of one part in the thousand has transmitted the disease. Not only, therefore, is there a vast difference in degree in the action of pepsine and infectious poison respectively, but whereas there is in the first place a quantitative relation between the agent and the manifest results, in the other there is no such relation whatever. A dilution, however great, of infecting material, produces the same results in kind and in degree as the undiluted agent. But there is a further extreme divergence in the modes of action of pepsine and infecting material. Probably pepsine tends ultimately to its own exhaustion, but certainly it tends to no self-increase. On the other hand, the most prominent character of infectious material is its multiplication; herein is a circumstance which totally destroys the analogy. Given a certain amount of pepsine, it will dispose to the solution of a certain amount of albuminoid matter; but a fragment from the resultant whole will induce no change on a second quantity of albuminoid substance, while a particle of infecting poison will modify a given organism, a fragment from this will induce like changes in another, and so on *ad infinitum*. The analogy between the two processes, there-

fore, is of the feeblest kind. Moreover, when pepsine is stated to induce zymotic changes, I cannot help considering it a misuse of terms, inasmuch as it induces none of the essential phenomena of true (reproductive) fermentation. If such action is termed zymosis, then the disposing influence of spongy platinum upon mixed oxygen and hydrogen, of black oxide of manganese on chlorate of potash in the manufacture of oxygen-gas, and any so-called catalytic action, must also be termed zymosis.

I consider, therefore, that the action of pepsine fails to explain the action of an infecting poison.

Pursuing our analytical method, we will next inquire into the nature of those solid elements upon which the action of an infecting poison is proved to depend.

The solid matters in vaccine occur in two forms—*leucocytes*, resembling pus corpuscles, and *granules* of extreme minuteness, not exceeding 1-20,000th inch in diameter. The former being very variable in number and irregular in occurrence in efficient vaccine, it would appear *primâ facie* that infection does not necessarily depend upon them; and Chauveau showed, that when they, alone and in their integrity, were employed for inoculation, the results were *nil.* When, on the other hand, the free granules were inoculated, infection was manifest. Further investigation showed, however, that the leucocytes contained free granules multiplying in their interior, and when these were set free by breach of continuity in the cell-wall, they were efficient like the other granules. Leucocytes may, therefore, be looked upon as receptacles of the poison-granules.

We will next more intimately consider the structure and character of the granules met with in vaccine. Here I cannot help urging that a tribute from all interested in the precise study of these questions is due to Dr. Beale for his patient and elaborate investigations, which have elucidated not only the characters of the vaccine elements, but the series of changes which occur in the eminently infectious cattle plague. It has been said that the poison of the latter is probably "of a kind which is, and always will be, undisco-

verable by the microscope."* But it appears to me that this finality, the tendency of which must be to discourage microscopic investigation, is quite unwarranted. On the other hand, where ordinary physical methods of investigation cease, this method begins, and of all others seems the most fitted to throw light upon the obscurity. In April, 1864, Dr. Beale† showed that vaccine, examined by very high powers, contained masses of germinal matter which exhibited active *vital* movements, *and on these living particles he considered the infecting property to depend.* (See Fig. 36).

In Dr. Beale's elaborate record of "Microscopical Researches on the Cattle Plague,"‡ he described as a cardinal feature of the disease the occurrence in a marked degree of masses of germinal matter on the walls of the minute blood-vessels of animals which had died of the disease. Frequently these were so disposed as to gravely interfere with the due circulation of the blood, and by their rapid multiplication could impose such barriers as to induce local congestions. In the discharges from mucous surfaces and in the milk such masses of germinal matter were abundantly found. The tissues corresponding to the eruptions on the udders, the villi and glandular follicles of the small intestine and the muscles also contained such masses which had evidently been undergoing rapid multiplication during the life-time of the animal. As in the case of vaccine, Dr. Beale said, "The germinal particles are, without doubt, the active agents, and it seems to me as much opposed to the facts of the case to maintain that the *materies morbi* of cattle plague and other contagious fevers is a material that can be dissolved in a fluid, and precipitated and reformed, as it would be to regard any living organism as the result of the concentration of an albuminous solution, and capable of re-solution and precipitation." The infecting particles "consist of a peculiar kind of living matter, the smallest particle of which, when supplied with its proper pabulum,

* Report of Cattle Plague Commissioners.

† Microscopical Journal, April, 1864.

‡ Appendix to Third Report of Commissioners, 1866.

will grow and multiply, giving rise to millions of little particles like itself, each having similar properties and powers. The only condition in which matter is known to exhibit these powers of self-multiplication is the living state."* (Figs. 37—40).

Granting for the purposes of argument that the infecting particles in disease are possessed of vital properties, whence are those particles derived ?

Dr. Beale's theory asserts that they are derived by direct descent from the living matter (bioplasm) of a normal, healthy organism. There is in ordinary life a progressive change in power in the bioplasm of an organism, though at an early date such bioplasm presented to the closest scrutiny no structural differences, but was of the hyaline character common to all matter possessing life. The embryonic bioplasm in the course of time becomes differentiated, and the exactly similar structureless material endowed with varying potentiality becomes muscle, nerve, or bone, or any of the other essential structures of the body, as the case may be. Bioplasm may, however, become turned from its ordinary course of developmental change, and may manifest increased rate of growth and, *pari passu*, degradation of formative power. The special properties of bioplasm are capacity for movement and the power of taking up materials in the medium which surrounds it, and converting it into the matter of itself. Such powers belong to living matter, and to living matter alone. It is common alike to separate organisms and to intrinsic parts of the same organism. The transition from health to disease may be a very gradual transition. Thus the rate of growth of bioplasm varies during health in obedience to various causes ; the white blood corpuscles, for example, increase in number when, from any cause, the blood current is retarded ; during hybernation in animals these white cells are vastly increased, and this condition constitutes a sort of borderland between health and disease. All the varying forms of living matter, which together constitute an entire organism,

* Report, *loc. cit.*, p. 149.

are capable, under certain circumstances, of giving rise to "*a common form of germinal matter or bioplasm differing in properties and powers from them all.*" Such is pus. This product is, moreover, capable of further and still further degradation, and constitutes, endowed with various powers, the infecting material of the various diseases we are considering. The death-producing disease germ thus "seems to have been derived from the living or germinal matter of man's own organism." As I understand it, therefore, by very slight gradations, the living particles which normally are the constituent parts of an organism, and subject to the general laws of nutrition of the entire body, may become invested with powers tending more and more to render them independent of the laws of the general organism, and to confer upon them individual proliferative power—until at length their vitality is independent of, and antagonistic to, the life of the containing organism, and by their struggle for vitality it perishes.

The various disease-poisons are germs or living particles endowed with properties varying in the different diseases, originally derived by changed conditions from the living material which constituted a healthy living organism, and capable of transmission from organism to organism, and of proliferation within such organisms.* Dr. Beale's theory, therefore, harmonises with the zymotic theory that has been enunciated, in that it considers the first cause of infection to be living matter, the symptoms to be due to the vital acts of such living matter, and the spread to the excretion and re-distribution of the living matter, increased and multiplied. The view does not, however, harmonise, in regard to the nature of the first causes, with some of the facts which we have just enunciated. Dr. Beale does not deny that many diseases are due to fungous organisms, but considers them to be local affections, not involving the blood, and confined to a part of the body. An exception,

* Cf. BEALE, Disease Germs—their Supposed Nature. London: Churchill, 1870. "Bioplasm and its Degradation, with Observations on the Origin of Contagious Disease," Quarterly Journal of Microscopical Science, vol. x., New Series.

however, must be conceded in the case of the silk-worm disease, wherein blood and tissues are undoubtedly invaded by parasitic vegetable growth, and this shows at least the possibility of such occurrences in higher organisms. Dr. Beale's theory regards the *bacteria* met with in the anthracic diseases as adventitious and non-essential.

At this point we will take up the theory of Professor Hallier—*that specific diseases are due to the influence upon the body of fungous elements of distinct morphological forms.*

We should enquire, however, *à priori*, whether there is any evidence to show that the minute elements of fungi, taken into the body in a manner analogous to that by which infection-particles can enter, are capable of inducing morbid phenomena.

Dr. Leonard Sedgwick says—"The following relation shows that the spores of some fungi do produce disease. The *Arundo donax* is much cultivated in France for industrial purposes. After the stems are cut, they are gathered into heaps and exposed to the air. In the course of time they often become mouldy, and the workers, adults, and children, are then frequently attacked by a strange, severe, and sometimes fatal malady. Dogs have been known to be similarly attacked after sleeping on the mouldy heaps. The disorder is described as follows:—fever, heaviness of head, vertigo, and swelling about the eyes and mouth, extending to the head, which often becomes very large. Then vesicles and pustules appear on the skin, often attacking the respiratory and alimentary mucous membrane, producing dyspnœa in the one case, and vomiting and diarrhœa in the other. At times there is great swelling of the genital organs, with much sexual excitement. This disorder is now admitted to be produced by the spores of *Ustilago hypodytes*, a form of smut, which begins by a grumous whitish mass of reticulated *mycelium*, growing at the expense of the infected plant, and finally becoming converted into a mass of round and often fœtid spores." *

* "A Report on the Parasitic Theory of Disease," Trans. of St. Andrew's Medical Graduates' Association, 1869.

Hallier contends that the *same kind* of particles which induces fermentation and putrefaction induces also infection in the various spreading diseases. *Micrococci* (or microzymes) are found by him in every infectious material. In the alvine discharges of diarrhœa, cholera, dysentery, enteric fever, *Micrococci*, sometimes varying slightly, but constant to the various diseases, are found in vast numbers. In measles they are found in the sputa; in small-pox and cow-pox they are shown in the contents of the pustules. In some forms of fever they are met with in the blood, and in case of scarlet fever "there is no disease in which they are so abundant." So, also, in constitutional syphilis, they exist numerously in the blood; and they are found in the exudation from chancres and in the discharge of gonorrhœa. The question at once arises—why do these, to a great extent similar, molecules, manifest specific variations in action, in cases of the various specific diseases? Professor Hallier answers, that they are intrinsically different, being capable of development into differing organisms,—that to each disease there is a specific parasitic microzyme,—and that, by cultivation, this fact may be demonstrated, for special forms in their higher development result, in case of the growing *Micrococci*, in every special disease, and their fructification yields *Micrococci* possessing infecting powers like their predecessors.

As an exemplification of his views of the causation of infectious disease, Hallier has chiefly taken cholera, and in its relations the theory has been the most completely worked out. The cholera *Micrococci*, when cultivated, yield various fungoid organisms, according to the soil in which they are sown; but when rice is chosen as the cultivative material a definite fungoid organism results,—a form of *Urocystis* which is known to affect the rice-plant, especially in hot climates. Thus Hallier thought might be explained the original cause of cholera—An unlucky individual might absorb, in India, where the rice-plant flourishes, some grain infested with the parasitic *Urocystis*,—the *Micrococci* thus derived might initiate in him the disease cholera, which he

could transmit to countless other individuals by means of his dejecta. It is only in tropical climates that the *Urocystis* can develope the perfect fructification capable of producing the malignant microzymes. Once produced, one individual could transmit enough to devastate a nation. It is not my purpose to enter at length into this question, the literature of which is now very extensive. I cannot but consider that the investigation is full of probable sources of error. Dr. Lewis has made, just lately, a series of investigations which tend to prove that *Urocystis*, exactly resembling, if not identical with, the *Urocystis* obtained by cultivating the *Micrococci* of cholera stools, can be obtained from the dejecta in cases of perfect health. He strongly combats Hallier's conclusions, and shows that his view of the causation of cholera, in so far as he traces it back to the smut of rice, is unsound.*

Hallier has pursued a similar mode of investigation in regard to sheep-pox. He believes the disease to be intrinsically due to *Pleospora herbarum*, a common parasite in hay, which can readily be transmitted to sheep. The microzymes in sheep-pox are exactly similar to those of the *Pleospora*, and by their cultivation lead to similar morphological forms. Evidence of the same kind, but manifestly incomplete, is adduced in reference to enteric fever, scarlet fever, gonorrhœa, syphilis, &c.

Dr. Salisbury has endeavoured to show that the disease called measles is due to the spores of fungi; he has adduced evidence to show that a sporadic form of the disease took its rise in some soldiers who slept on beds of mouldy straw.

I cannot help considering that the conclusions, in so far as they relate to *distinct morphological fungoid forms* as causes of specific diseases, are, from the existing state of the question, quite unwarrantable. If there were this relation

* On all these points see HALLIER, Gährungsercheinungen, p. 86. Das Cholera-Contagium: Leipsic, Engelmann, 1867. SANDERSON, Twelfth Report of the Medical Officer of the Privy Council, pp. 248 *et seq.* Dr. LEWIS'S Report, &c.

between parasitic vegetable growths, common to ordinary growing plants, and infectious diseases, surely more evidence of such relation would be likely to appear on the surface; it could not fail to be noticed in regard to the geographical or local distribution of disease. When parasites affect vegetables, these do not occur on isolated individuals, but spread over a pretty wide area: the influence that would affect one person within this area would probably affect others, and it is scarcely likely that the relation of causation would be overlooked. The evidence which has traced specific parasitic fungi as causes of specific diseases has been of the most indirect description. Cholera has not shown itself to become grouped around plains of diseased rice, nor measles to assert itself where mildew is most manifest. But these considerations are very far from disposing of the question of fungoid particles as causes of infectious disease. The properties of such particles do not depend on their morphological forms alone. There are, it is true, morphological specificities, but there are specificities which are not morphological. The members of a single botanic family differ widely in their properties, and no botanist could, from their structural characters, predict which were hurtful and which harmless. Nay, to take a still closer analogy, in the case of the higher forms of fungi,—mushrooms,—these are so very similar that it is sometimes impossible to distinguish from each other those which nevertheless possess totally different properties. To continue the illustration—it is an ascertained fact that the very same mushrooms (*i. e.*, in no way differing in their morphological characters) differ in reference to the soil in which they grow. The nature of the soil will make all the difference between wholesomeness and acridity. There is, therefore, nothing improbable in the theory that, although the fungoid particles which induce specific diseases resemble each other very closely, or even absolutely, in morphological characters, they may nevertheless possess powers of morbid action which no cultivation nor means of physical examination could detect. Just as Dr. Beale's germinal matter possesses varying pathological

potentialities, so Professor Hallier's *Micrococci* might have the like attributes.

But are there any real grounds for believing that fungi are really concerned at all in the causation of infectious disease? This is the question at issue between the degraded-germinal-matter theory and the fungus-germ theory.

In the case of the silk-worm disease there is really no room for doubt that the parasitic fungus is essentially the cause of the disease. In the anthracic diseases of cattle, the evidence that we have already adduced seems very strong. That bacteria are, in this disease, present in enormous numbers in the blood is asserted by independent and competent observers; and that the blood has suffered a decomposition is no less admitted.

An addition to the evidence concerning the causation of the disease by bacteroid organisms has been made, in a peculiar way, by MM. Raimbert and Davaine, independently of each other. It had long been supposed that the disease was diffused by the agency of flies. It was found that common house flies and flesh flies could absorb the infecting principles of anthracic blood: bacteria were found in numbers both upon and within their bodies. Guinea-pigs inoculated with flies thus affected died of malignant pustule, and their blood was found full of bacteria.*

Dr. Beale says it is not proved "that the bacteria were the poisonous agents, and many circumstances render it probable that other matters suspended in the blood constituted the real virus, while the vegetable organisms were but harmless concomitants."† But it must be allowed that precisely similar objections would lie against the theory that the morsels of protoplasm, as seen in cattle plague,

* RAIMBERT, "Récherches Experimentales sur la transmission du Charbon par les Mouches" (Comptes Rendus de l'Institut, 1869). DAVAINE, "Etudes sur la Contagion du Charbon chez les Animaux Domestiques" (Bulletin de l'Académie de Medicine et Gaz. Hebdomad., 1870. DOBELL'S Reports, 1870, p. 33.

† Disease Germs, p. 68.

are the *veræ causæ*. We have seen that the decomposition of putrescible material outside the body is really and essentially due to such motionless bacteria (*Micrococci*) as are observed in such great numbers in the blood of anthracic disease, and there seems no escape from the conclusion that the decomposition of the blood in infectious disease is dependent upon them. Again, in regard to cholera and typhoid, there appears to be a marked relation between their causation and the entrance of a poison-material in putrescence, and consequently accompanied by the presence of fungoid particles. The evidence is almost incontrovertible, that the two diseases mentioned are in most instances propagated by drinking water contaminated by the sewage dejecta of individuals suffering from the special infection. Such matters are in putrefactive decomposition even before excretion from the communicating individual, much more whilst sojourning in the watery medium by which they are conveyed. There is evidence tending to show that it is only at a certain stage of putrefaction that such excreted poison manifests its morbid effects. From a chain of evidence as remarkable as it is circumstantial, Dr. Macnamara is able to assert that "so surely as water contaminated with choleraic dejecta is capable of reproducing the disease when consumed during the vibrionic stage of decomposition, so certainly it may be drunk with impunity after this stage is over and when various forms of ciliated infusoria have replaced the vibriones." This tallies with the observations of Thiersch, who by administering cholera-evacuation to animals, concluded that the substance capable of infection was formed in from two to six days of spontaneous decomposition; and those of Sanderson, who found that it was efficient in inducing cholera symptoms in mice up to the sixth day of its decomposition when it became inert.* Dr. Macnamara attributes the infective power to no organised but to a developed organic material; but he allows that bacteria invade even the epithelial cells cast

* Ninth Report of Medical Officer of Privy Council, p. 451.

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away in the dejecta and float freely in the alvine fluid (see Fig. 35). We have before seen that the vital phenomena of fermentation are due not to the motile vibrios but to the motionless *Micrococci*. It is surely as legitimate to attribute the causation to organised material proved to possess destructive and decomposing power, as to assign it to a hypothetical organic poison about which nothing is known.

The fact remains *that one of the co-efficients of infection is a given stage of the putrefaction or fermentation of infective material;* and this obtains additional light from the observation of Davaine, that the bacteridia of anthracic disease become by the continuance of putrefaction dead and inert, the inoculation of the material containing them being of no avail in inducing the specific infection.

Dr. Beale objects to the fungus-germ theory that the germs are so abundantly present in the air we breathe and in almost every part of the living body, that their relation *cannot* be one of causation; and those that are met with in diseases are rather consequent upon the morbid changes than themselves the causes of them. But giving such considerations their due weight, it is at least as legitimate to admit a variation of power in such germs from harmlessness to fatality, as to attribute it to morsels of bioplasm which are not fungoid in their origin. But Dr. Beale further objects that the theory does not explain the phenomena of infection in case of dissection wounds, because the period of greatest virulence of the infecting material produced is very soon after death, and "before the occurrence of putrefaction and the development of bacteria." But Dr. Beale has himself shown that bacteria exist in the body during the activity of life; and by Mayrhöfer and others they have been demonstrated in these very wounds. The fixing of the commencement of putrefaction in such a case must be purely arbitrary.

Dr. Beale says, "No one has shown that if inoculation were effected while the patient yet lived, the results would be in any way different;" and he adds a positive opinion, that the poison of dissection wounds, like that of small-pox

and syphilis, is developed during life. But I conceive that there are most potent objections to this view. It is generally considered that it requires no special morbid condition to confer upon a body the faculty of transmitting *post-mortem* infection. If such poison were capable of development during life, it would be a terror to those who would put in force the transmission of blood from a living to a moribund individual in order to save the life of the latter. We know that the infection of normal blood is attended with no untoward sign; witness the results of transfusion which has been practised with such benefit; yet we know that inoculation soon after actual death is attended with direful consequences. A short time may suffice to induce these changes; but to my mind it is as legitimate to attribute the potential activity to a germ which, existing in close relation to the body during life, is ready, in obedience to certain laws to spring into a new activity in order to accomplish the disintegration of the dead organism, as it is to assign such power to any other form of living matter which cannot in such an instance be pointed out, and the function of which cannot be explained. And the fact of the virulence ceasing at a certain period of decomposition is illustrated by the facts just quoted in relation to the poisons of cholera and the anthracic diseases. I fully concede that if we accept the theory that fungoid germs can cause infectious disease, we must accord to such germs specific potentialities, harmless or harmful, as must also be accorded to Dr. Beale's bioplasm; but I consider that we are not bound to Professor Hallier's hypothesis of specific morphological forms as inducing specific diseases.

The most important evidence on this part of the question has been added by Semmer.* Having confirmed the existence of fungoid particles in the blood of glanders and the anthracic diseases of cattle, he tried many experiments on healthy beasts, by injecting fungus elements into their circulation. The injection of *Micrococci ferments*, of the

* VIRCHOW'S Archiv., April, 1870, p. 158.

Arthrococci of acid fermentation, and of ordinary *Penicillium spores*, produced no result whatever—the beasts remained in perfect health. When, however, the *Penicillium* was cultivated upon the blood of an animal infected with anthracic disease, injection of its spores induced in another animal disease and death. "Here," says Semmer, "through the injection of fungus-spores and *Micrococci* which had been cultivated upon anthracic blood, the anthracic disease was reproduced; the ninth day after the injection came the outbreak, and on the tenth the foal died." This observation lends colour to the hypothesis I have enunciated that the distinctive properties of the various fungus-elements which induce spreading diseases are due to the conditions of soil and surroundings, and not to special morphological characters.

The question between Professors Beale and Hallier, concerning, as it does, the remote origin of infectious disease—for according to both theories, in the vast majority of cases, such diseases are propagated by means of vitalised matter of specific endowments transmitted from the sick to the healthy—is really but a "question du milieu." The investigation of the original causation of infectious disease is beset with difficulties, and it is possible that either or both these observers may be right. The great practical consideration is, whether or no they are correct in the view that they hold in common—that the infecting material which induces the specific transmissible diseases consists of particles endowed with life.

It now becomes a question between the germ theory and the physicial theory.

We should first understand what is meant by the word "germ," for the term has been used with different renderings. Some have seemed to consider that the epithet "germ theory" conveys an awfully iconoclastic doctrine, that seeds or ova of disease, in portentous form, are constantly seeking a soil in the bodies of human kind, and that the supporters of such a doctrine hold that the air is thick with "germs." I have already in these pages conveyed an

idea of what a germ is in its several relations, from its invisible, or scarcely visible, condition in fermentation and putrefaction: we have seen that the physical form and the morphological manifestation of such germ are dependent upon the pabulum with which it is supplied, and the various physical conditions by which it is surrounded. The term germ implies no more than the minutest conceivable particle of matter which possesses life. Such life may belong to it as a living portion of a living organism, or as an organism entire in itself. There can be a germ of an epithelial cell or of a pus-corpuscle, as there can be a germ of an *Amœba* or a *Penicillium*. In relation to the causation of infectious disease, a germ may be considered, as Dr. Beale has defined it—*a particle of living matter which has been detached from already existing living matter, and this living matter came from matter of some sort which lived before it.**

Let us now enquire into what is meant by the physical theory. According to this theory, as enunciated by Dr. B. W. Richardson, infectious diseases are due to organic poisons, which are colloidal solids, transmissible by physical intermedia, destructible as dead organic matter is destructible, and the action of which is purely physical on the body. Such particles originate in one of two modes—by contact with an organic poisonous secretion, pre-existing and derived from an animal previously affected, or by direct decomposition of a secretion which is thus rendered noxious. In previously enunciated physical theories it has been considered that the poison actually increased in the organism by its own operation; but Dr. Richardson considers that this work of multiplication is done by the secreting powers of the recipient organism—"the force of secretion is the force of reproduction, and ceases with the death of the affected animal."

First, as regards the prime cause. This theory would ascribe the property of a morbid poison to a particle of solid matter so minute as to be absolutely invisible. Surely no physical

* Disease Germs, p. 10.

method of investigation enables us to probe the mystery of such tremendous potentiality. The term "physical," applied in this sense alone, can be nothing else than a misapplication of terms, for the action of such a fragment of matter, if physical, must be incomprehensible; if chemical, inexplicable. A poison that is merely physical is the same in the past, the present, and the future; it selects no season and respects no person. If from the same sample of vaccine I inoculate a large number of infants, I find that some of the children refuse to present the signs and symptoms of such inoculation: would you find a like insusceptibility to any known poison which operated in virtue of its physical attributes? When the infective power is said to be invested in a particle of dead organic matter, nothing save a paradox is presented to the mind. Next, as regards the action of such a molecule upon the organism. The very mode of experimentation which has determined the colloidal character which it is admitted that disease-poisons possess is demonstrative of the fact that they are insoluble—if insoluble, how can they act as a physical poison? By catalysis? I have shown the weakness of the analogy which is adduced with such processes. Do catalytics communicate to other matter by their physical influence powers identical and commensurate with or even transcending those which they themselves possess? Does pepsine make the albuminous substance it contributes to digest pepsine like itself? To make the theory coherent, the secreting glands should be the laboratories and emunctories of the various poisons; but there has never been any proof that typhoid can be communicated by the saliva, or measles by the dejecta, while there is very direct teaching that the parts whereupon the diseased action is chiefly manifest are most powerful in transmitting disease—the poison of cholera by the evacuations, diphtheria by the exhalations, &c. In many diseases it is proved that not the secretions but the blood has the most power of infection. The obvious facts of the multiplication of a poison within a living organism has always been a stumbling-block in the

way of any hypothesis that disease-poison operated in any directly physical or chemical manner. Dr. Richardson has ingeniously overcome this by throwing the work of reproduction upon the recipient vital organism ; but I do not see how this helps the physical theory. If it be urged that the dead organic molecule catalytically influences the living molecules of the body, and these again influence others so as to produce in their substance a dead organic poison like that which first induced the change, I can only regard this as a series of postulates unsupported by a single proof, entirely antagonistic to our knowledge of organic matter in any state whatever. And if this hypothesis be rightly termed "physical," the usual connotation of the term "physics" must be changed to suit the occasion.

Resumé.—From the utterances of some authorities it would appear that the germ theory is a wild hypothesis,—an impatient generalisation from imperfect data. I cannot but consider that the term "extravagant" might with far greater reason be applied to the so-called physical theory.

I trust that the preceding pages have shown that this germ theory (a *germ* signifying no more than a particle, however minute, of living matter) is built on no hastily or imperfectly contrived foundation, but is a deduction from a mass of circumstantial evidence, and the result of the convergence of many modes of thought.

Considering the evidence which has been adduced as to the constancy of the relation between disease-poisons, disease-processes, and minute portions of matter possessing vital endowments, I conceive that this relation cannot be considered one of co-existence merely, but (taking all the collateral evidence into consideration) of causation.

The potential energy of a disease-poison is due, and can alone be due, to a particle possessing life. Such a particle possesses, not the reactions of a chemical compound, but the complex reactions of a living being. It does not possess the chemical characters of a definite organic compound, but the complex albuminoid constitution of the material which pertains to living beings. It is rendered inert by agents

which would be inoperative on a chemical substance, by heat* and by cold; and the chemical agents which influence it exert their power, not in virtue of their chemical properties, but in so far as they are poisons to animal or vegetable organisms. Dr. B. W. Richardson, in opposing the "germ theory," has credited its exponents with the view that germs "are indestructible by the ordinary processes of nature." I am at a loss to conceive from what observation of any exponent of the theory he has obtained such an extraordinary inference. In considering the poisons capable of inducing disease as living germs, I consider them amenable to all the destructive influences to which all low forms of life are subject. Instead of being indestructible they are liable to arrest of vitality, by conditions which, in case of unorganised material, have no effect whatever. The *Aphides* of summer live their little life and die in a day; the coolness of a breeze can kill them. The same rotifer which could be dried and preserved, to resume vitality when moistened with water, can be seen, when swimming in the element, to die from a reason which it would be impossible to explain. Infusoria which crowd a solution, manifesting the fullest vigour of life, will become motionless and dead in an instant if the fluid in which they swim be rendered acid. It is *because* such particles are living that they succumb to such apparently slight and often inexplicable influences. To this behaviour of living matter is due the distribution throughout the world, in various localities, of the faunæ and floræ that the most befit the various climes, so that the face of the globe is not overcrowded with a dangerous exuberance of living things. That, when once infected by the germs of a special disease, the system should be rendered insusceptible, or imperfectly susceptible, of a like influence, is surely more capable of explanation by the idea of the crop having organically changed the soil than by the mode of operation of a physical poison, which is a poison alike now and at any

* Vaccine, according to Dr. Henry, loses its properties between 120° and 140° F.

time in the future. Was an organic poison ever known that could be once administered with the effect of rendering its recipient for ever after proof against its effects?

The consideration that these disease-germs have always specific attributes, and are, save in the most exceptional cases, transmitted from one human organism to another, is sufficient to dispel any false idea that the common air we breathe is thick with germs of disease. Amongst the myriad harmless germs of animal and vegetable life which the air contains, a disease germ does not intrude unless some centre of infection is near, or unless it is imported by some physical means. Sporadic cases of infection may with great probability be said to be due, for the most part, to the occult importation of disease germs, or to the renewal of life, by some accident of their surroundings, of some that have lain dormant for indefinite periods; although of course it is possible to explain such cases by the notion that the complex conditions of vitalised matter and external circumstances which induced the primordial germ of the specific disease have chanced to recur.

As in fermentation and in putrefaction, infection is due to the influence of vitalised molecules, only the endowments of such molecules are variable.

CHAPTER XIX.

MALARIA.

In the preceding chapters we have considered only those diseases which are directly transmissible from an infected to a healthy individual. In the special diseases of malaria there is no such lineal transmission, but a centrifugal emanation from the source whence the disease-poison is produced. In considering the nature of the *materies morbi* of such

diseases, we lose the argument deduced from the proliferation of the poison within the recipient system.

As before stated, the portions of the world-surface whereupon putrefaction is manifest were almost from time immemorial considered as centres for the dissemination of disease. Moisture and heat, which increased the conditions of putrefaction, increased the danger.

> " Ubi putrorem humida nacta est
> Intempestivis pluviisque; et solibus icta."
>
> LUCRETIUS.

The ancients recognised a material poison developed from centres of putrescence as the cause of the diseases which became manifest. This obscure cause they called an "occult venom," a "deleterium quid," or, as Hippocrates regarded it, a "something divine." Other sources of putrefaction besides those of marshes naturally existing upon the earth were also recognised as centres of infection. The following quotation from Mead (1702) may be interesting at the present time, as conveying both a lesson and a caution. He says, "All authors do agree in one great cause of pestilential distempers, especially in armies and camps, to be dead bodies lying exposed and rotting in the open air; the reason of which is plain from what we have been advancing;* for battles being generally fought in the summer it is no wonder if the heat, acting upon the unbury'd carcasses and fermenting the juices, draws forth those above particles, which in great quantities filling the atmosphere, when they are inspired and let into the stomach, do affect it after the manner already described."

The obvious effect of the exhalations of marshes is the production of ague and its kindred affections. Until 200 years ago, before the time when drainage was practised, and when much of England was a swamp, ague was a most fatal disease. James I. and Cromwell both died of ague.†

* He has been discussing infection.

† WATSON, Lectures on the Principles and Practice of Physic, vol. i., p. 747.

To develope the poison of ague, heat and moisture are necessary; but it is disseminated in greatest degree when the surface of the soil, previously flooded, has become dry; it is evidently carried by the wind, but the presence of even a small surface of water interrupts its course; it does not rise high in the air, but "loves the ground." It may be that, though developed upon the warm and liquid surface, the very moisture, by inducing viscidity, prevents the air from detaching and carrying away its particles; when drying has taken place the air wafts them, but if they pass over the surface of water they tend to adhere thereto, and the air becomes freed from them. Moreover, physical obstacles, such as trees or high walls, have been observed to intercept the poison of intermittents.

The special poison evolved from marshes, taken into the system in an imperceptible manner, produces profound effects upon the nervous system, evidenced by the peculiar phenomena of coldness and shivering, followed by heat and sweating. These effects, recurring at intervals, may last for many years or for a life-time in those once affected; and frequently in the subjects of them there is manifest a continuous morbid sensitiveness of the nervous system. The poison, moreover, impairs the blood-making powers of the organism, and gives rise to structural alterations of the spleen, liver, and kidneys, especially the first. "Perhaps," says Dr. Bence Jones, "it acts first most strongly on the nerves that regulate circulation, causing for a time contraction of the arterial vessels, and consequent suboxidation everywhere. But this soon passes into a state of peroxidation, partly from the obstruction of the small arteries increasing the pressure of the heart, and partly from the changes going on in the textures and in the poison by which it is partially destroyed. During the remission *the poison is reproduced until sufficient, in from one to three days, is formed to go through the same actions again*."* The question occurs, What is the nature of this poison? To arrive at the answer

* Lectures on Pathology and Therapeutics, p. 230.

to this, we will consider the matters which are demonstrated to be evolved from marshes, so that we may adopt the logical method of exclusion.

The air of marshes contains only the ordinary gaseous matters of putrefaction: it is needless to say that these do not, *per se*, produce the specific phenomena of ague. The organic matter is not proved to differ from that given off in like conditions. The evidence all converges to show that the poison-agent is solid, insoluble, capable of being carried by currents of air, and filtered therefrom by physical obstacles. It is not alone by the air, however, that the poison finds its entrance into the body; it can enter with drinking-water. From the time of Hippocrates downwards it has been shown that drinking the waters of marshes will produce ague and enlargement of the spleen. The facts in support of this view are notorious in the South of India: instances are recorded that when the inhabitants of a district, among whom ague has been rife, have become supplied with well-water instead of the marsh-water they were formerly accustomed to drink, the epidemic has ceased. Facts teaching a similar lesson have been observed in this country and in France.*

We cannot fail to see that an essential concomitant of marsh-poisoning is the existence of matters in a state of putrefaction. Analyses show that the most disease-producing marshes contain a large amount of vegetable organic matter.† Conditions of putrescence are necessary for the production of malaria.

The effects of the malaria poison are like none of those produced by organic matter in any state; it is said, even by those who adhere to the hypothesis that it is merely an organic substance, to be reproduced in the body, yet we know of absolutely no organic matter whatever that is self-multiplying; there is a constant relation between the phenomena of ague poisoning and the existence of vegetable matters in a state of putrefaction.

* See PARKES, Practical Hygiène, 3rd ed., p. 70.

† *Ibid.*, p. 294.

From our former investigations we find that this latter process essentially implies the existence of minute particles of matter in a living state. The adequacy of such minute particles to produce phenomena of disease as complete as those of ague, we may consider as proved by the data contained in former chapters. It remains for us to ask—Is this relation one of coexistence merely, or are the poisons of malaria, like those of infectious disease, living particles possessed of different powers of propagation in the two cases?

We will then turn to the analytic method. What is contained in the air of marshes? As we have said, there are the ordinary gases and volatile compounds of putrefaction. Moscati, in 1818, made the following observation in a rice-field of Tuscany, a centre of malaria. He suspended at a little distance from the ground glass globes filled with ice, and examined the condensed vapour which trickled from the outer surface of the glass. The liquid thus obtained speedily putrefied. Many other observations confirmed this. Liebig said, "All observations made upon gaseous contagia show that these are matters occurring in a state of decomposition. Air which is charged with them, deposits, on the outside of vases filled with ice, water, which contains a certain quantity in solution. At every moment this water changes its state; it becomes troubled and putrefies."* Here we have the facts read by the light of the old motion hypothesis—change of state without a cause.

In 1864 Lemaire and Gratiolet investigated in the manner already indicated the air of one of the most unhealthy marshes of Sologne. The condensed vapour was found to form a colourless limpid neutral fluid. Microscopic examination showed it to contain spherical, ovoid, and fusiform spores, and a large number of pale cells of various sizes. In course of time there was proliferation of cells, such as we have described in the course of putrefaction. Comparative experiments with the air of different localities showed that there were great differences in its putrefiable power.

* Chimie Organique, t. I., p. 191.

Since 1862 Dr. Salisbury, of Ohio, also investigated this question. He discovered in the condensed malarial vapour oblong nucleated cells, which he believed to be derived from the *Palmellaceæ*. He considered that a definite relation existed between a certain palmelloid plant (*Gemiasma*) and the production of ague. Moreover, he describes the characteristic oblong *Palmella* spores as existing in the saliva and expectoration of patients suffering from ague. He relates a strange synthetic experiment. He obtained some earth from a malarious bog, and placed it in boxes upon the window-sill of a bedroom in a locality perfectly free from ague. Two young men occupied this bedroom: in a fortnight both of them suffered from tertian ague, the other occupants of the house escaping unaffected. Dr. Salisbury relates two other cases with a like result.*

Hallier has, however, adduced a potent argument against the view that intermittents are *directly* due to the *Palmellaceæ* described by Salisbury. These *Palmellaceæ* belong to the *Algæ* and are chlorophyll-producing plants: all such plants need the light; it is probable that their very existence is dependent upon light. It is, therefore, very unlikely that they should undergo any proliferation within the body wherefrom light is necessarily absent. Though they are not direct, they may, however, be indirect agents; for they can determine the formation of fungus-elements which are common to putrefactions.

Let us briefly consider the position to which we have arrived. We find all marshes to contain putrefying organic matters, as in all other putrefactions multitudes of living molecules occur within them in all the activity of development, growth, and multiplication. Their products and their producing living *Micrococci* are exhaled into the air; even distilled water when agitated with the air thus given off becomes putrid, as determined by Thénard and Dupuytren; moreover, the living particles can be actually

* See Report on the Parasitic Theory of Disease, by Dr. SEDGWICK. Trans. St. Andrew's Graduates' Assoc., 1869.

collected from the air, and their development and multiplication observed. In an analogous manner the air from any source of putrefaction can be shown to contain *Micrococci*, and, according to Lemaire, to convey such putrefaction-inducers to other putrescible material, with rapid induction of all the phenomena of putrefaction in the latter. Evidence of botanic specificity of these minute particles of living matter, however, to my mind (as in the case of the infectious diseases already discussed), signally fails.

Seeing all these relations, I do not think we can fail to come to any other conclusion than that the phenomena of malaria, like those of infectious diseases, are due to minute particles of bioplasm; and that these are derived from, and identical in nature with, the minute particles of vegetable protoplasm which determine putrefaction.

There is, however, a signal difference in property between the particles which produce intermittent and those which induce infectious disease. The former abide in the organism of the recipient and produce their morbific effects, but are not cast off to infect others: once introduced they are indigenous to the recipient organism.

As I have said in the case of specific infectious disease, I believe that the peculiar properties of these molecules cannot be explained on botanical or morphological grounds. Like all living particles they are possessed of potentialities and powers shown in the wondrous variety of nature, but explained by no philosopher—morbific germs are indistinguishable from harmless germs, but their powers are different from them and from each other.

While all other theories fail, while all speculations as to organic matter as a cause of malarial disease are purely conjectural, the view that the producing causes are vitally endowed seems to me to rest on a sound basis. This view explains satisfactorily the distribution, the causation, and the phenomena of intermittent fever.*

* For an interesting speculation concerning the *modus operandi* of ague-spores, see Dr. MORRIS's Essay, Germinal Matter and the Contact Theory, p. 83.

CHAPTER XX.

CARBOLIC ACID AS A DISINFECTANT.

Very soon after the extraction of coal-tar in the manufacture of gas for illuminating purposes, it was found that this substance had a power akin to those of the then known disinfectants. The antiseptic qualities of the heavy oil of tar were described in 1815 and 1837, by MM. Chaumiette, Guibourt, and Siret respectively; the difficulty in the use of this substance was its almost complete insolubility; many persons attempted to remove this difficulty by incorporating it with chalk, gypsum, or other coarse powders. In these powders the percentage of the antiseptic contained could necessarily be but small—2 to 3 per cent, but they proved very useful. Afterwards saponine was employed to make the oil of tar into an emulsion readily miscible with water; this, first introduced by M. Le Beuf of Bayonne, was a great improvement. It is still probably preferable to any preparation where a slow and gradual antiseptic action is desired, which shall be long persistent. It was found that the antiseptic action of coal-tar depended chiefly on three ingredients—aniline, benzine, and carbolic acid; of these carbolic acid is proved to be by far the most practicable agent. In 1854 and 1860 in Paris, animals in a state of advanced putrefaction were injected with coal-tar, with the result of their perfect preservation and desiccation. Runge, who in 1834 discovered carbolic acid, established also its powers as a disinfectant and a means of preventing putrefaction. Liebig in 1844 confirmed this. In 1851 Mr. Crace Calvert, in Manchester, practically demonstrated that it could preserve flesh from putrefaction even when injected in a diluted solution into the arteries; and that urine and other putrescible compounds could be most efficiently preserved without decomposition, and without emitting any noxious odours.* It was no doubt Lemaire who first on

* Edinburgh New Philosophical Journal, 1855.

any large scale employed carbolic acid as a disinfectant. He found that it was to a sufficient extent soluble in water, and, therefore, could be employed without difficulty. In the proportion of 1 part to 1000 it would disinfect fœcal matters. In the caserne of the Quay D'Orsay, 15,000 litres were disinfected in 48 hours by 200 grammes of carbolic acid. Lemaire found that the sewage thus disinfected when used as manure was not impaired in its fertilising power, and in no way injured seeds or crops to which it was applied. He advised also the addition of carbolic acid to stagnant waters which might be centres of infection. It might, he said, be added to drinking water in the proportion of 6 to 12 drops to a litre; its odour and taste, however, were an objection.

It was necessary to observe whether the frequent employment of carbolic acid and the inhalation of its vapour could produce any deleterious effects. A careful examination showed that the work-people engaged in its manufacture and those in whose trades it was employed suffered in no way from its influence.

In December, 1865, the employment of carbolic acid in any notable degree commenced in this country. After the researches concerning its nature and relative powers undertaken by Dr. Angus Smith, Mr. Crookes, F.R.S., further investigated it, and tested its powers in regard to the then fearfully fatal epidemic of cattle plague. Mr. Crookes signalised its success (1) in the prevention of the plague in the case of farms which were situated in the area or in the march of contagion. The sheds in which the animals were placed were whitewashed with lime, to which solution of carbolic acid had been added; carbolic acid was added to the organic refuse, and its vapour was disseminated through the air of the stalls. The evidence seemed to show that in cases of four farms the disease was kept away by the means employed. Again, by the adoption of similar measures, it was thought (2) to preserve individual animals, although the plague had invaded the farm to which they belonged. In 1866, the dreadful outbreak of cholera called

again loudly for the adoption of measures of disinfection. We find now that carbolic acid had taken its place among the most frequently employed disinfectants. It was used most extensively in the country, and health officers of many parishes in London specially mentioned it as employed, many of them speaking strongly as to its advantages. Dr. Letheby said of its use in the City of London, "Carbolic acid has been used as the sole agent of disinfection for privies, drains, and sinks, and for the sewers and public roads." It was recommended as one of the agents which most commonly prove useful for artificial disinfection on a large scale, in the memorandum on Disinfection issued by Mr. Simon, as Health Officer to the Privy Council. Since this time it has been very largely employed, and seems to be the agent *de resistance* in case of any zymotic outbreak, as that of typhoid fever, scarlatina, and small-pox, in various parts of the country.

We may next inquire as to the position of carbolic acid among agents known as disinfectants. Infection in its widest sense means the communication to an animal body of an agent from without, which will produce in that body the phenomena of disease. This definition would, however, include not only those poisons, organic or inorganic, the effects of which administered by the stomach are well studied, and whose agency is an established truth, but also of those living things as *Pediculi* and the itch insect, which are also demonstrable causes of conditions of disease. In the restricted sense in which the term infection is used, it is held to mean the introduction of those more subtle external agencies which are supposed not only to change the organic relations of the system of the individual subject to their influence, but to be transmitted from individual to individual.

Disinfection is the destruction of the disease-producing agents which give rise to those affections known as zymotic. Disinfection, then, is a therapeutic means of the highest importance. It is the treatment of the disease of the great body politic, and bears the same relation to the state that the medicinal remedy does to the individual.

I. **Disinfection of Organic Matter in a State of Putrefaction.**—So strongly has been felt the relation between putrefaction and infectious disease, that hitherto the action of a disinfectant has always been tested by its power of overcoming the noxious exhalations of decomposing matter.

Correlations of Putrefaction and Disease.—That the noisome emanations from putrefying substances can induce symptoms of disease is matter of common experience. The noxious material is evidently conveyed by the air, for it is by breathing the mephitic emanations that the ill-effects are produced. Upon what portion of such emanations does this power depend? The first question which would arise would be, Is such power dependent on the gases evolved? But these are well-known and have been carefully studied. Their influence is noxious, but the symptoms induced by them do not resemble those induced by the exhalations from putrefying material; and to produce these effects they must be inhaled within a confined space. The gases of putrefaction on the other hand, according to the well known laws of gaseous diffusion, are soon distributed throughout the neighbouring atmosphere, and thus their own special effects annulled. It must be concluded, therefore, that the poisons given off from the foci of putrefaction are not gaseous, though they may be carried by gaseous intermedia, by currents of air, &c. Are the mephitic poisons simply organic? On this point, so far as precise investigation can show, we have an answer—the chemical substances arising from matters in a state of putrefaction are well known, and none of them are capable of communicating, especially in the minute amount in which they must necessarily exist when inhaled, the precise phenomena induced by foul emanations.

We have already considered that putrefaction itself is not only accompanied by, but is essentially dependent upon, minute portions of living matter. We have seen by what an array of evidence such living particles are traced as causes of disease, how they can be actually discovered

in the atmosphere, and how the air is capable of wafting them from place to place. It is scarcely needful to point out how strongly the conclusion is forced that the danger of the pestiferous emanations of putrefying material is due to minute masses of living matter given off from the various foci.

Again, the ingestion of material in a state of putrefaction as a cause of disease is simply a matter of common observation. Animals refuse food which is tainted. Many instances of poisoning by mouldy bread have been recorded. Preserved meats and sausages eaten when in a state of putrefaction have proved poisonous in many instances.

The relation between putrefaction and many forms of disease, therefore, is very intimate. There are not only the relation of resemblance in their general phenomena, but the relation of similarity in their causes, both being due to living molecules, and the relation of direct causation for matters in putrefaction are, without any doubt, causes of disease.

I have already shown the power of carbolic acid to prevent fermentation and putrefaction. It remains to ascertain its *position amongst other agents which have like powers.*

It may be seen that such agents differ in kind, and produce their effects in different ways. In relation to their mode of action they have been divided accordingly as it was supposed they produced these effects:—(*a*) by oxidation; (*b*) by deoxidation; (*c*) by organic unison with the putrescible or fermentescible body, as certain metallic salts; (*d*) by mere contact as catalytics, or, as Dr. Angus Smith terms them, colytics. I demur entirely to this classification.

Of the so-called oxidising disinfectants, we may take chlorine and permanganate of potash as examples. Chlorine decomposes water, forming hydrochloric acid and liberating oxygen. Thus it is an indirect oxidiser. There can be no doubt that chlorine oxidises the gaseous and the volatile products of putrefaction. All fœtid odours it at once destroys; this is purely in virtue of its chemical powers. It is a type of a *deodorant;* throughout a long period this marked property, which was evident to the

senses, was adduced as a proof that it was pre-eminent among disinfectants. This cannot now be held. It is known that, though the gaseous products of putrefaction may be converted into inodorous compounds, yet the *process* of putrefaction may go on all the same. The gases are evolved, but when evolved they are changed; the chemical products are attacked first by chlorine and its allies; the living things, animalculæ, and the vegetable organisms, are attacked last.

Permanganate of potass is a most powerful oxidising agent. It gives up its oxygen to every organic body with which it comes in contact. In water itself its condition of oxidation is seen to vary and produce different tints at different times and under different conditions. In my experiments I found that the fermentation which half a grain of permanganate of potass or of chloride of calcium was powerless to arrest, was, under identical conditions, immediately and permanently arrested by 1-30th grain of bichloride of mercury, or 1-10th grain of sulphuric acid. Dr. Angus Smith has found that the vapour of carbolic or cresylic acids, or of creasote, or of oil of mustard, will perfectly arrest the putrefaction of meat which in ozone rapidly decomposes; that vapour of chlorine, bromine, or iodine will preserve flesh which turns putrid in peroxide of hydrogen. From these data it may be fairly concluded that the oxidising power of any chemical body is not an index of its power as a disinfectant. And reflection would show how inadequate the proportion of a so-called oxidising disinfectant would be to perform the function required of it if it acted simply by oxidation. It is a large proportion if we employ 5 parts of chloride of lime to disinfect 100 parts of organic matter. Yet how insufficient this would be to oxidise the mass. Still more is this evident in the case of permanganate of potass, of which so much smaller a proportion is commonly used. The total available oxygen in permanganate of potass is 128-316ths, or less than half its weight. The quantity employed would be insufficient to oxidise a fraction of the putrescible matter to which it is added.

Then as regards deoxidising agents. The action of sulphurous acid, which is so powerful a preventive of fermentation and putrefaction, cannot be explained by its deoxidising property, which must be strictly limited by the amount of oxygen which it can absorb by its conversion into a sulphate.

Then as to metallic salts, the infinitesimal amount which will arrest fermentation and putrefaction affords an argument that they do not act by chemical union with the mass with which they are mixed. Moreover, the differing power of each cannot be explained on known chemical laws. As I have said, 1-30th of a grain of bichloride of mercury will arrest the fermentation which is not in the least degree influenced by the presence of half a grain of chloride of zinc.

Lastly, when we turn to carbolic acid itself, we find, first, that its chemical constitution is similar to the hydrocarbonaceous matter which itself forms so much of the bulk of a fermentescible mass. Its *constitution*, therefore, cannot explain its properties. Then we turn to discover its chemical properties, but find that its action is in no way explained by these, for it is singularly destitute of any direct *chemical power*. From the data, I contend that we cannot fail to arrive at this conclusion—*viz., that the chemical constitution and the chemical properties of a body are in no direct relation whatever with the power of that body to arrest fermentive or putrefactive changes.*

The preceding pages have shown that in the processes of fermentation and of putrefaction, the chief phenomena are those of the evolution of animal and of vegetable life. It is proved that those agents which prevent putrefactive or fermentive change kill these low organisms. Those which merely act on the gaseous products of putrefaction, altering their chemical constitution, are *deodorants*, but are not necessarily *disinfectants*—they do not annul the process of decomposition, though they take away the noxious character of the gaseous products which are the indications of its existence.

The distinction, therefore, between antiseptics and disin-

fectants is no longer tenable. All disinfectants act in virtue of, and in proportion to, their power as septicides.

Carbolic acid, when added to moist putrefying matter, acts only on the process of putrefaction. It arrests it by killing the germs which give rise to it. It does not act upon the noxious exhalations already given forth. It is not a deodorant except by prevention of gaseous evolution. In the presence of moisture its power is certainly inferior to that of many other antiseptics.

Comparative Antiseptic Power of Carbolic Acid in Presence of Water.—As I have already shown, the power of carbolic acid to arrest fermentation of sugar is far inferior to that of some metallic saline antiseptics. To investigate the comparative efficiency of antiseptics in arresting putrefaction is not easy, but much may be learned from the labours of Dr. Angus Smith. The evolution of gases is a necessary accompaniment of putrefaction—the measure of the quantity thus evolved in a given time affords at least an approximative estimate of the degree and extent of putrefaction. Dr. Angus Smith used serum of blood as a putrescible material, and this was mixed with twice its volume of water. The following table is condensed from Dr. Angus Smith's work, omitting those instances in which the substances used gave rise to evolution of gas greater in amount than obtained in case of normal blood uninfluenced.

*Amount of Gas evolved when Disinfectants act on Organic Substances in Water.**

Disinfectant employed.	Proportion to bulk.	Gas evolved per week in c.c.
1. Chloride of zinc	1 : 1000	1·40
2. Arsenious acid . . .	,,	1·60
3. Sulphate of copper . .	,,	3·10
4. Bichloride of mercury .	,,	4·50
5. Carbolic acid . . . . . (Efficiency decreased with higher concentrations).	1 : 10,000	18·96

* Extracted and condensed from ANGUS SMITH'S On Disinfectants.

Amount of Gas evolved when Disinfectants act on Organic Substances in Water (continued).

	Disinfectant employed.	Proportion to bulk.	Gas evolved per week in c.c.
6.	Nitrate of iron	1 : 1000	23·30
	Sulphate of iron . . .	,,	
	Sulphate of alumina . .	,,	
7.	Cresylic acid	,,	28·00
8.	Chloride of lime . . .	,,	30·30
9.	Chloride of sodium . .	,,	25·20 / 34·30
10.	Chlorate of potash . .	,,	31·30
11.	Blood alone	—	38·00 / 52·00

In another set of experiments, Dr. Angus Smith endeavoured to estimate the comparative efficacy of certain antiseptics in the presence of water to prevent the evolution of sulphuretted hydrogen. From a review of the table given in Dr. Angus Smith's work,* the following appears roughly to express the relative repressive power of the various agents employed:—

Relative Power of Various Agents in Suppressing the Evolution of Sulphuretted Hydrogen.

1. Most efficacious	Bichromate of potash. Chloride of aluminum. Chloride of lime. Sulphite of soda.
2.	Nitric acid. Cresylic acid. Heavy oil of tar (water solution).
3. Least efficacious	Carbolic acid. Hydrochloric acid. Sulphuric acid. Heavy oil of tar (soda solution).

There is thus agreement in the evidence, that whether it is a question of the prevention of fermentation, or (so far

* Pp. 89, 90.

as evolution of gases is a test of it) of putrefaction, carbolic acid is inferior to metallic salts as an antiseptic when water is freely present.

Disinfection of Sewage.—Modern investigation tends to show that many spreading diseases are due to the contamination of water or air with sewage matters. Notably this is the case with regard to cholera and typhoid fever. Where the sewage exists together with a considerable quantity of water, carbolic acid in solution is, in my opinion, *not* the best agent to employ as an antiseptic. Here I find myself at variance with Dr. Parkes, who says of the tar acids, "These substances are the best sewage deodorants and arresters of putrefaction that exist."* He adds, as a general conclusion, "On the whole the carbolic acid preparations appear the most generally useful as sewage deodorants, or the Süvern deodorant,† and after them the ferric chloride (Fe_2Cl_6)."

It would appear, from the considerations I have already adduced, that, to obtain satisfactory results, carbolic acid, when used to disinfect sewage, must be employed in much larger proportions than is common at present. And, according to Dr. Parkes, sixty grains of the crystals are requisite to disinfect the daily solid excreta of one person.‡ The effect, moreover, of carbolic acid which is volatile is not so permanent as that of the metallic salts. With all deference to so high an authority as Dr. Parkes, I cannot help coming to the conclusion that, where it is a question of obtaining an antiseptic effect upon a mass of putrescible material which is abundantly mingled with water, chloralum or the metallic salts are to be preferred to carbolic acid. When, however, it is a question of the *immediate* disinfection of the semi-solid excreta, or, as I have termed it, of *primary* sewage disinfection, then a strong solution of carbolic acid, or emulsion of oil of tar, is highly valuable. Or over the

* Practical Hygiène, p. 363.
† Quick-lime, coal-tar, and magnesium chloride.
‡ Lancet, Nov. 21, 1868.

surface of the mass may be dusted the powders which we are about to consider.

Disinfectant Powders.—Since 1858 crude carbolic acid, mingled with various substances, in the form of powder, has been used for disinfecting purposes.

1. The disinfectant powder of *MM. Corne* and *Démeaux* (1858 and 1859) consisted of plaster of Paris and coal-tar.

2. That of *M. Bouchardat* contained 1 part of carbolic acid in 1000 of plaster of Paris.

3. That of *Parisel* contained 1 part of carbolic acid to 100 of coarse meal, and 4 of lard or fat.

4. *McDougall's powder* contains about 33 per cent of carbolate of lime, 59 per cent of sulphite of magnesia, the rest being water.

5. *Calvert's powder* contains from 20 to 30 per cent of carbolic acid mixed with the powdered refuse from alum works.

When one of these powders (the most efficient being probably the last two) are dusted over a putrescible mass, they prevent putrefaction by poisoning the germs in the air before they reach the mass. They thus filter the air of the elements which dispose to putrefaction. According to Dr. Parkes, half an ounce of either Calvert's or McDougall's powder will preserve four ounces of sewage from 18 to 21 days. Whilst, to my mind, Calvert's powder is rather more efficacious, McDougall's has the advantage of a less powerful odour. Besides the influence of carbolic acid in these powders, I think their efficacy is probably due to another cause, which we are about to consider—their power of absorbing water from a moist putrescible material.

The Dry Earth System for Preventing Sewage-Putrefaction.—It is impossible to question the fact that the addition of dry earth to moist sewage matters will entirely prevent odour, and arrest putrefactive change. The importance of the system initiated by the Rev. H. Moule cannot be doubted, though there may be differences of opinion as to the different conditions to which it is best adapted. A pound and a half of dry earth thrown over a dejection, solid and liquid, will deodorise and will arrest all

putrefactive changes for months,—in fact for such time as the mass remains dry. Whence is this power derived? Can it be the chemical influence of the earth itself? No—for it can be proved that the sewage-laden soil, however impregnated, if only it be dry, serves to prevent decomposition. It seems to me that the only rational explanation of this phenomenon, and that a perfectly satisfactory one, is that the property of the earth is due to its dryness, and to its capacity of molecular union with water; it absorbs *water* from the putrescible material, which element, as is collaterally proved, is essential to the proliferation of those organised molecules which are the disposing causes of the putrefactive change. Dry earth is a disinfectant because it robs putrefying matter of one of the essentials of putrefaction—moisture. When under any circumstances the supply of dry earth might fall short, its combination with carbolic acid, or the use of a carbolised powder, would be most desirable. It could not fail to aid the antiseptic power of the earth—to make a little go a long way; the presence of carbolic acid would not injuriously affect its fertilising power on the land. We have seen that the latter is not impaired when carbolic acid is not present in excess, and, moreover, the volatility of the latter soon permits it to be dissipated.

Whenever an antiseptic effect is desired, in any case, aqueous admixture should be reduced to a minimum; water favours the development of organisms, and diminishes the power of an antiseptic.

Disinfection of Water.—The measures which prevent putrefaction on the surface of the earth, and which forbid the possible entrance of sewage matters into water used for drinking purposes, go far towards complete disinfection; not entirely, however, for it is proved that rain-water may become contaminated with organised particles from the air. Lemaire recommends the addition of carbolic acid to drinking water; but I consider it totally unfit, for to disinfect sufficiently would require a proportion which would render the fluid nauseous. Filtration through charcoal, or boiling in the first place, and the addition of little of an

alkaline permanganate (Condy's fluid) in the second, to remove all organic impurity, are the best methods for the disinfection of drinking water.

Disinfection of Air.—The necessary corollary from the views enunciated as to infectious disease and the nature of the poisons emitted from putrefying materials, is that the air contains disease germs which it can transport from the various foci to various individuals, or from one individual to others. The molecules of putrefaction, in various stages of development, have been seen and described by many observers. Lund described them in the air of hospitals. Trautman* found those minute bodies which he terms "decomposition-cells" to be far more numerous in ill-ventilated rooms; they multiply extremely rapidly, but their rate of multiplication is greatly increased by the presence of sulphuretted hydrogen in the air. Dr. Ransome found numbers of fungoid cells and growths in the human breath.† There is abundant evidence that the air contains numbers of organised particles possessed of various attributes. The question occurs, "Can those particles which convey the infection of certain diseases be destroyed by volatile or gaseous antiseptics?" On this point we have the strong evidence that the analogous molecules which induce putrefaction can be, according to our observations, entirely destroyed or poisoned.‡ Trautman found that a great restrictive influence was exercised upon the appearance of decomposition-cells in a room wherein carbolic acid or coal-tar was used.

Comparative Value of Air Disinfectants.—In the observations quoted on the growth of fungi,§ iodine, creasote, and carbolic acid were found to be the most efficient agents. Dr. Angus Smith made a series of observations on the effect of volatile bodies in preventing *putrefaction*. The following is an epitome of his results:—

* Die Zersetzungsgäse, 1869.

† Journal of Anatomy and Physiology, May, 1870.

‡ See Chap. XII. See also Papers by the Author in Chemical News, Nov. 18 and Nov. 25, 1870.

§ P. 105.

Order of Efficiency of various Volatile Substances in Preserving Meat.—I. Cresylic acid, fusel oil. II. Carbolic acid, creasote. III. Oil of mustard. IV. Wood naphtha, oil of bitter almonds. (II., III., and IV., preserve equally long with I., but colour of meat not so well retained.) V. Acetic acid, pyroligneous acid, essence of pine apples. VI. Coal naphtha. VII. Oil of juniper, aniline, oil of peppermint, oil of rue. VIII. Turpentine, oil of lavender, oil of valerian, phosphorus and water, oil of cumin, oil of rosemary, oil of hops. IX. Oils of cinnamon, thyme, orange-peel, bergamot, pepper; naphthaline, nitrobenzole, camphor, oil of lemons, aniseed, gum, assafœtida, crude Canadian petroleum.

Dr. Crace Calvert also has recorded experiments in which meat was suspended in the air in bottles, over known quantities of the various substances recorded. The meat was subject alone to the air thus influenced.*

Antiseptic used.	Became tainted.	Putrid.
Permanganate of potash	2 days	4 days
Chloralum	2 days	10 days
McDougall's powder	12 days	19 days
Chloride of lime	14 days	21 days
Tar oil	16 days	25 days
Chloride of zinc	19 days	—
Carbolic powder	Did not become tainted, but dried up.	
Carbolic acid	Did not become tainted, but dried up.	
Cresylic acid	Did not become tainted, but dried up.	

In the cases, therefore, both of putrefaction and of fungoid manifestation, the most efficient poison to the germs in the air is the vapour of carbolic acid and its allies. There is every reason to suppose that there is a like action upon the analogous molecules which induce infectious diseases: the results of daily experience seem to corroborate the theoretic conclusions.

We must be careful in this question of prevention of

* Chemical News, December 9, 1870.

spread of disease by the air, to bear in mind the difference between *deodorants* and *disinfectants*. The fœtid gases evolved from putrescent matter are indications of the existence of putrefaction, and are in themselves nauseous and noxious; but they are not the actual agents either of putrefaction or of transmitted disease. To deodorise is to remove these nauseous smells; to disinfect is to destroy the organised causes. Chlorine may attack the organic products but leave the organised producers unscathed. Sulphurous acid is powerful both over the products and the producers, but it is dangerous to be breathed. Carbolic acid is exceedingly efficient over the producers but inert as regards the products. If we believe organised forms to be the efficient means of propagating disease, carbolic acid is the aërial disinfectant *par excellence*. It may be mingled with the water used to cleanse the room; thus its vapours rise into the air. Or cloths may be sprinkled with it and left, so that it may evaporate at the ordinary temperatures. Or if rapid vaporisation be desirable, the cloth may previously be dipped in hot water. Or the carbolic powders may be sprinkled about the floors so that the vapour may rise into the general air. I cannot help thinking that the practice of exposing permanganate solution (Condy's fluid) in vessels about a sick chamber is utterly futile. It is quite true that this agent is a most valuable oxidiser; it yields up its available oxygen to almost any oxidisable substance with which it comes in contact, but it is essentially non-volatile; it cannot in any appreciable degree influence the air in its vicinity. The effect could only be manifest on that minute proportion which passes over its immediate surface. It is surely puerile to think that this could have any appreciable antiseptic effect on the air of a room.

Disinfection of the Air of Rooms.—When the room is occupied, this can be done by exposing to the air porous cloths steeped in or sprinkled with carbolic acid; or the carbolised powders before mentioned can be strewn about the floor. Care must be taken to avoid the caustic effects

of the acid on the skin on the part of those manipulating it. The quantity of carbolic acid thus given off is limited, but I have shown that a very small proportion of the agent in the air is sufficient to arrest septic changes. For carbolising the air of large chambers, wards of hospitals, &c., the following method has been put in force:—A broad piece of absorbent canvas doubled and joined is stretched like a jack-towel between two rollers. The lower portion dips into a trough containing liquefied carbolic acid. A handle at the side enables the canvas to move like an endless band between the two rollers. As the moistened portion becomes dry from evaporation, a fresh piece is drawn up and thus the evaporating surface renewed. This was designed at the London Hospital.

For complete volatilisation carbolic acid requires a very high temperature. An elegant method of effecting this in a progressive manner, and thus of carbolising the surrounding air, has been introduced by Messrs. Savory and Moore.

The vaporiser consists essentially of a metallic plate heated by a spirit-lamp or wax mortar, over which is suspended a glass vessel containing liquefied carbolic acid. By means of a dropping tube the carbolic acid is made to fall regularly, drop by drop, on the heated plate, whence it is dissipated in vapour. This may be recommended as a very simple and effectual means of rendering the air of a sick room antiseptic.

The improved vaporiser now supplied by Messrs. Savory and Moore (see Fig. 41), with wax mortars and new dropping bottle, leaves nothing to be desired for convenience of manipulation and satisfactory working.

When the room is unoccupied carbolic acid may be employed instead of sulphurous acid as a disinfectant. The fumes of burning sulphur used for this purpose offer certain difficulties and dangers. The molten sulphur may occasion serious chances of fire; and it has bleaching qualities on any textile fabrics. Not only are these dangers avoided by the use of carbolic acid, but

the latter has a more persistent effect as an antiseptic (see page 105).

For thoroughly carbolising the air of an unoccupied chamber, I advise (1) the exposure of an abundance of the liquid acid upon porous cloths in the room; (2) evaporating the acid in an iron ladle over a brazier in the centre of the room, or pouring it upon some strongly heated bricks.

Disinfection of clothing can be readily effected by carbolic acid. For this purpose it is much more efficient than subjection to heat. Some hot sand, or heated bricks wrapped in flannel, should be placed at the bottom of a box, and carbolic acid abundantly sprinkled over them. The clothing should then be introduced layer by layer with carbolised powder between them. Then the box should be firmly closed with a lid. It is scarcely needful to say, that all living parasites, as *Pediculi*, are destroyed by this method, as well as all germs of disease.

CHAPTER XXI.

THE EXTERNAL EMPLOYMENT OF CARBOLIC ACID.

(1) **Counter-irritants.**—If strong carbolic acid be applied to the surface of the skin, an immediate tingling and burning sensation is experienced; the spot affected becomes of a white colour, the neighbouring skin assumes a red areola, and the symptoms become similar to those attending the application of a powerful caustic. In the course of a few days there is exudation from the surface attacked by carbolic acid; sometimes this is dry and scaly,—any considerable moisture is an exception,—but frequently there is some formation of pus, which resembles that in cases of

impetigo. The irritation, after a single application, persists for a protracted time,—from a fortnight to three weeks,—but after the first symptoms, which pass away in a few hours, the pain is inconsiderable. This caustic property of carbolic acid may, I think, be taken advantage of. I have employed it in many cases where I have considered pronounced counter-irritation of the chest advisable. It has the merits of convenience and easy application, and its effects are so persistent that it is scarcely ever necessary to re-apply it. Of course it is in this relation impossible to speak of its merits in any very definite manner; it is difficult to dissociate any good effects observed from those of the concurrent agencies employed in the treatment. Whatever good effects it possesses must be chiefly, if not entirely, due to its counter-irritant power; and it is certainly not received by all good observers that counter-irritation is of any value. The method of employment is to paint, by means of a camel's hair pencil, the liquid carbolic acid over the spot which it is desired to counter-irritate; it is better, however, to surround the area acted on with a little olive-oil. I have taken notes of sixteen cases which I have thus treated; eight of these showed symptoms of improvement, in which the plan adopted might fairly be considered to have a share, whilst in seven no benefit could be supposed directly to accrue from the treatment. The cases were chiefly those of pulmonary tubercle of the second stage, in which moist sounds were a prominent sign; two of them were cases of emphysema with congestion. The subjective signs of improvement were chiefly diminution of cough and relief of chest-pain; the objective signs were a diminution of the moist sounds heard by the aid of the stethoscope. This was marked in one case,—D. H., male, aged 30,—with tubercular deposit in the apices of both lungs. Two days after the application of carbolic acid beneath each clavicle (though no other change had been made in his treatment), the copious moist *râles* had disappeared, and concurrently the cough and expectoration were greatly diminished. Again, when moist sounds were observed in the scapular region, in the same

case, the application of carbolic acid was followed by a disappearance of the *râles*.

Carbolic acid, externally applied, is not only counter-irritant, but

(2) Anæsthetic. An observer may easily convince himself of this by applying a little to the tactile surface of the finger. In this situation the primary irritation is accompanied with very little pain, and the impairment of tactile sensibility is very obvious. I think, also, that this property of carbolic acid can be put to practical use. The servant of a patient of mine once asked my advice concerning a very painful whitlow of the forefinger. Having some carbolic acid at hand, I thoroughly covered the inflamed portion of finger therewith; the application was unattended with pain. A few days afterwards the skin over the whitlow was dry, and there was fluctuation beneath it. When I freely incised it, the patient did not feel the incision. I think this plan of treatment—of applying strong carbolic acid over the pointing portions of boils, or over a limited surface of the skin covering superficial abscesses, with a view of producing cuticular anæsthesia—might fairly be tried with advantage.

Since writing the foregoing paragraphs I have seen some important papers corroborating the opinions I have expressed.

Mr. Erasmus Wilson * employed carbolic acid to control the morbid irritability of the glans and prepuce of an officer affected with disease for which the application of *potassa fusa* was necessary. The application of the caustic was thereby rendered almost painless. Mr. E. Wilson has employed it frequently since, always with a most satisfactory result. "It benumbs the surface, it dulls the excessive sensibility of the superficial nerves, and it thereby permits the caustic action of our remedies, with a great reduction in the amount of pain."

A careful investigation of this property of carbolic acid

* Journal of Cutaneous Medicine, June, 1870.

has been made by J. H. Bill, M.D., Surgeon U. S. Army.* He found that the application of carbolic acid to the skin so impaired tactile sensibility that it became not only impossible to distinguish the two points of an ordinary æsthesiometer, however widely separated, but even to distinguish the presence of one. By drawing a brush dipped in liquefied carbolic acid over the course of the radial artery, the sensibility was so blunted that subsequent incision of the integument was painless. For twelve months Dr. Bill employed carbolic acid as a local anæsthetic in all minor cutting operations.

Dr. E. R. Squibb † considers cresylic to have a more powerfully anæsthetic effect than carbolic acid: the faculty is shared by many aromatic oils and turpentines,—notably oil of peppermint.

With the idea of utilising the counter-irritant and anæsthetic effects of carbolic acid, I have largely employed this agent in lotions and liniments; I have used it dissolved in or mingled with water, or dissolved in olive-oil. The strongest proportion used was 1 in 8, the weakest 1 in 64; the former produces an immediate rubefacient effect in the case of the admixture with water, but not so in the case of oil. Of thirty cases of pulmonary disease, chiefly phthisis, in which I thus employed it, it seemed to do marked good in thirteen. The assurances of the patients that the chest-pain, which often was very severe, was greatly alleviated by the application, could not be misinterpreted. In some cases, also, the cough became less distressing. The following was the mode of employment. In the case of liniment, it was ordered to be rubbed into the chest, or the seat of pain, by means of a piece of flannel, usually twice a day; the lotion was applied by means of a sponge, with brisk rubbing. When it was thought that the coldness of the application was undesirable, the patients were instructed to heat the sponge previously by hot water. In another class of cases

* American Journ. of Med. Sci., October, 1870, p. 573.

† "Anæsthetics," read before Med. Soc. of State of New York, February 8, 1871, p. 29.

my experience tells me that there is no room to doubt the efficacy of this plan of external treatment; I mean in cases of hooping cough in children ; I have very largely adopted it, and am convinced of the relief afforded. I have recommended the saturated aqueous solution, as well as a mixture with oil (1 part in 8), to be sponged over or rubbed into the chest, by means of a piece of flannel, at stated intervals. Carbolic acid has also been frequently employed as an ordinary caustic. When applied in its pure state to a mucous surface it immediately turns the latter white, by coagulating the albumen of the tissues ; moreover, by the affinity of the strong acid for water it tends to cause shrinking of the mucous structure. I have many times employed it in cases of enlarged tonsils, the size of which, after two or three applications, become very materially diminished. It is also useful, in cases of ulcerated surface, where a caustic is called for. It has thus been employed in cancer. Mr. Turner, of Manchester, found it an efficacious application to *piles:* it coagulates the contents, and, by constriction, empties the sac, which ultimately becomes obliterated. Mr. D. Davies also speaks of the value of its application in cases of *internal piles* and *rectal fissure.*

Uterine Diseases.—Dr. Lloyd Roberts, of Manchester, has recommended the application of carbolic acid instead of nitrate of silver in ulceration of the os and cervix uteri with or without hypertrophy, chronic inflammation of the uterus and cervix, with excoriation and follicular disease of the cervical canal. It is thus applied: after introduction of the speculum, the surface of the ulcerated portion is wiped clean by a piece of lint, and then touched with another piece of lint, which has been dipped into the acid liquefied by a few drops of water. The white appearance at once indicates the spot covered by the acid, and care should be taken to avoid touching with it any portion of the vagina. Any superfluous acid should be immediately absorbed by a bit of dry lint or cotton-wool, and it is better to apply a little olive oil. A camel's-hair pencil or gum elastic catheter should be used when it is desired to introduce the

acid into the cervical canal. The application of the acid may be made once or twice a week. Dr. Roberts says, "I have found carbolic acid an application sufficiently powerful not only to heal the breach of surface, but to remove the hypertrophy of the uterus so frequently arising from inflammation and ulceration of that organ." The sympathetic pains quickly subside, and the flooding, occurring sometimes as a symptom of the disease, is controlled and ultimately cured. Applied to the canal it does not cause contraction, which may follow the use of stronger caustics.

It may also be employed with advantage, instead of nitrate of silver, to *chancres* and *syphilitic sores*, in males or females.

Weak solutions of carbolic acid, as *intra-uterine injections*, have been used with great advantage. After parturition, especially when the lochial discharge is scanty and fœtid, or where there has been reason to fear septicæmia, Dr. J. G. Wilson, of Glasgow, recommends its use. Among cases calling for its employment are those in which there is reason to suspect retention *in utero* of any portions of placental structures, those in which the fœtus is putrid, or where the utero-vaginal canal contains decomposing coagula.* Thus, it is useful after abortions.

Stimulant Application in Skin Diseases.—Carbolic acid has been thus used in lotions, ointments, and liniments. In many cases it is asserted to have been very useful, but experience of its good results is not uniform; and this can scarcely be wondered at when we consider the properties of carbolic acid as sedative and caustic, stimulant and anæsthetic —blowing, as it were, hot and cold, and varying in its effects upon the varying conditions of the nerve-structures. Lemaire has adduced many instances of the value of carbolic acid externally applied in diseases of the skin.† In *ecthyma* it caused rapid cicatrisation when used in solution as a lotion, and applied strong as a caustic to the non-ulcerated pustules, it caused them to pass rapidly away. In *eczema*

* Glasgow Medical Journal, May, 1869.

† De l'Acide Phénique, p. 535, *et seq.*

cure is, according to M. Lemaire, rapidly effected. He recommends a 1 per cent aqueous solution for the treatment of chronic eczema: the addition of vinegar favours penetration through the skin. Sometimes a glycerine solution acts well, though glycerine almost annuls the stimulant effect of carbolic acid upon the skin. The effects when the lotions are applied in the treatment of eczema are, almost immediate cessation of the itching, rapid diminution of the hypertrophy of the skin, and falling off of the crusts and scales; in *eczema impetiginodes* any ill odour is at once removed; excoriations and ulcerations heal rapidly. M. Bazin, Dr. Whitehead, Dr. Simos, and many others confirm these results, but it is allowed that in some cases the treatment is not so successful.

In *Psoriasis* very good results have been attained. Lemaire recommends a lotion of 1 per cent solution of carbolic acid in equal parts of vinegar and water; sometimes glycerine solutions are better; sometimes there are no good results. M. Bazin has used it in this affection with much advantage. Dr. Macnab* has strongly recommended it as an ointment (one part of acid to four of lard) in cases of *psoriasis*. In an inveterate case he found under the treatment that the diseased epidermic scales fell off, desquamation was arrested, and the skin began to assume a healthier aspect. Oxide of zinc ointment being then employed, cure was effected. Dr. Liveing also believes it to be in like cases a remedy of undoubted value.† Dr. Neumann, of Vienna, agrees that it is useful in scaly skin diseases, especially in their early stage, and in *lupus*.‡ Mr. S. John Coleman has cited cases which he considers to show the extreme value of carbolic acid applied as a lotion in *chronic eczema* and in *impetigo larvalis*. He used, however, so weak a proportion (20 minims of acid to 8 ozs. of glycerine and water) that some might be sceptical as to the share of carbolic acid in the causation of the results. He subsequently, however, employed stronger solutions.

* Lancet, March 19, 1870, p. 408.

† *Ibid.*, p. 602.

‡ Pick's Arch. für Dermatol. und Syph., Part III., 1869.

Dr. Mann, of Brooklyn, New York, has also employed it in chronic eczema. In a severe case he caused a solution of half a drachm of carbolic acid in 4 ozs. of water to be applied three times a day to the eruption. "The effect was immediate; the vesicles disappeared promptly, producing a slight exfoliation, and did not return, except a few groups about the neck, which two or three applications of the solution removed."* It was equally efficacious in severe *impetigo* and *psoriasis inveterata*.

Mr. Edgar A. Browne's experience of carbolic acid in skin diseases is not so favourable. In *eczema* he thinks "there is nothing peculiar in its actions, nor can any result be attained which cannot equally be effected by the tarry or mercurial stimulants in common use." In *psoriasis* "it cannot be compared with tar:" it sometimes increases the irritation it is intended to allay.†

In *elephantiasis* carbolic acid has been employed externally with great advantage. According to M. Bazin it is preferable to anything hitherto employed. In *lupus* excellent results have been recorded by MM. Lemaire, Prat, and Bazin, by Mr. Campbell de Morgan, and Dr. Whitehead, of Manchester. The last-mentioned uses an ointment of half a drachm of carbolic acid in an ounce of spermaceti ointment.

Parasiticide.—Inasmuch as the destruction of low forms of organisation is the most remarkable property of carbolic acid, it would be strange if this could not be put in practice in the treatment of parasitic disease. In 1860 Lemaire published cases of the rapid cure of *scabies* both in man and dogs by the saponaceous emulsion of coal-tar; subsequently, in other cases, Lemaire used a 5 per cent solution of carbolic acid with pyroligneous acid added to favour the penetration through the epidermis. *Acari* were discovered after the application dead; cure was very rapid and perfect. Similar success followed cases treated by Drs. Regnault and Prat. In case of the scabies of animals, also, the employ-

* New York Medical Journal, Sept. 1868, p. 515.

† Practitioner, Dec. 1869, p. 352.

ment of carbolic acid was extraordinarily successful. Experience sufficiently shows that carbolic acid can cure scabies; but, after all, this is not the real practical question—which is, is it preferable to all the other means of cure which have been for so long adopted? One circumstance in its favour is, that besides its power as a parasiticide, carbolic acid has a special property as an anæsthetic. I have proved this valuable quality in cases of lichen where the itching has been extreme. Whether, however, the solution of carbolic acid can be brought in relation with the *acari* in their hiding places to destroy them more rapidly than they can be destroyed by other methods, or whether the extensive cutaneous application may not in some cases induce untoward symptoms—these are questions which await solution by extended experience. Dr. Zimmermann, of Braunfels, has employed carbolate of soda, and believes it to be almost a specific for itch. He caused a lotion, containing from 23 to 46 grains of carbolate of soda to the ounce of water, to be well rubbed into the parts twice daily. In two or three days even inveterate cases were completely cured.* In cases of epizoa which infest the head, carbolic acid has proved a valuable means of extermination.

In *epiphytic diseases*, also, it has been proved to do great service, and formulæ for its application are given in most works on skin diseases; glycerine is generally employed as the vehicle. I am convinced that glycerine decidedly impairs the power of carbolic acid in destroying parasitic vegetable growths. Acetic acid is recommended by the French authorities in order to favour the penetration of the carbolic acid through the skin. For the formula, see Appendix. The difficulty is the volatility of the carbolic acid; it may evaporate before its task is accomplished. In several cases of eczematous affections not parasitic, I have employed with a most undoubted success a powder consisting of starch and carbolic acid. This powder is ordered to be kept in a muslin bag (in a bottle or box wherein volatilisation is prevented), and fre-

* Die Praktische Arzt, March, 1869.

quently dusted over the parts. In parasitic disease I feel very strongly that the best course is first to apply the acetic solution of carbolic acid, then to dust over the surface the carbolic powder; the latter can be frequently renewed; thus the volatilisation of the carbolic acid first applied is impeded, the acid itself is renewed by the re-application of the powder, and the epiphytic growths fail to obtain the moisture which is necessary to their vitality.

The coal-tar emulsion was used by M. Minière, of the "Institution des Sourds-Muets," in Paris, in cases of *fœtid otorrhœa* with the most complete success. I employed an aqueous 1 to 2 per cent solution of carbolic acid in a case of *ozæna* with the result of a perfect abolition of fœtor and gradual amelioration of all the symptoms. Lemaire advises the aspiration of air impregnated with the vapour of the agent. In fœtid discharges from the uterus it has been used both as lotion and in vapour with success. I have myself employed both the 5 per cent watery solution and the liniment composed of 10 per cent carbolic acid in olive oil with most striking advantage in cases of otorrhœa. A few drops only are to be introduced into the external meatus night and morning until a cure is effected; usually this rapidly occurs. In *ozæna* emulsion of coal-tar has been employed with much benefit.

Summary.—From the foregoing considerations and from personal experience, I think I am justified in arriving at the following conclusions regarding the external employment of carbolic acid :—Carbolic acid is (1) *an efficient counter-irritant* of very easy application; its effects vary with its dilution; it may be employed weak or strong according to the result desired; (2) *a local anæsthetic;* it may be used with great advantage for minor surgical operations on the superficial structures; (3) *a disinfectant* of undoubted value of fœtid secretions and of decomposing and dangerous matters; (4) a useful agent in the local treatment of diseases of the skin, but one to be used with discrimination and according to a defined knowledge of the object desired.

In *Lichen* it is a valuable anæsthetic. It certainly greatly

relieves the itching and promotes a rapid cure. It should be used in weak solution in water as a lotion, 1 to 2 per cent.

In *eczema* it is valuable as a sedative and gentle stimulant; care must be taken that its action in the latter relation be not in excess. I am accustomed in ordinary cases of eczema to order the strong (5 per cent aqueous) solution with the following directions:—The lotion is to be at first diluted each time of application with three times its bulk of warm water, and the surface of the eczematous patch is to be sponged with it, or a piece of lint soaked with the lotion thus diluted is to be applied. The strength can be increased by degrees, less and less water being added. In eczema with profuse moist secretion I know of no agent so valuable as the carbolised starch-powder. It is of the most simple application, and the recoveries under its use are remarkably prompt. In cases in which this moist eczema occupies the folds of skin, as it frequently does, in the neck or flexures of the joints, it is often very difficult to apply or to retain for any period in due apposition a liniment or an ointment. In these cases the powder is exceedingly useful; the parts can be dusted with it frequently with very little trouble; or the surfaces can be first sponged with the lotion or liniment and then the powder applied. In some cases of eczema, especially when the skin is much thickened, the aceto-carbolic lotion is to be preferred.

In *impetigo* it is very useful. When this disease co-exists with *Pediculi*, as is common in neglected children, I have frequently seen the 5 per cent lotion effect a cure in two or three days. Where there is much moist purulent secretion it is very valuable; sometimes I have found the aqueous, sometimes the oily, solution the more useful; but in all such cases the powder is very advantageous. When the disease is evidenced by dry caked scales, neither liniment nor ointment has appeared to be of much service. In these cases I am accustomed to order the scalp to be washed with warm water containing a little oatmeal, and then an ointment composed of equal parts of creasote-ointment and white precipitate ointment. My own experience is against the use

of carbolic acid mingled with lard as an ointment; the lard impairs the action of carbolic acid, so that if it is weak it is inert, and if strong irritant. I have, however, found great benefit from a preparation which I have styled amylaceous ointment, which is much used at the North-Eastern Hospital for Children, and which has an importance viewed from the economical side of the question. This ointment, a formula for which appears in the Appendix, consists of a rather stiff starch commingled with a small proportion of olive-oil, and containing 5 to 10 per cent of pure carbolic acid. The same basis can be made a vehicle, instead of lard, for almost any medicament to be used as ointment.

In *parasitic skin affections* carbolic acid may be employed with much advantage, but a caution must be entered against its employment in anything like large proportions over an extensive surface. General toxic effects may result from its too liberal use. In these affections a $2\frac{1}{2}$ per cent acetic solution is to be recommended.

In local *erysipelatous affections* all the applications are useful. This point may, perhaps, be best illustrated by the following case:—*Francis M.*, aged 9, applied with erysipelatous inflammation, involving the forehead, eyelids, and the left cheek; it resulted from a wound received four days before. Ordered a purge of calomel and jalap and 10 grains of sulphite of soda three times a day. Fourth day, wound suppurating freely; ordered liniment of carbolic acid. Seventh day nearly well. Tenth day discharged quite well.

In other such cases I have found the carbolised starch-powder most valuable.

CHAPTER XXII.

THE TREATMENT OF WOUNDS: THE CONTROL AND PREVENTION OF SUPPURATION.

The application of carbolic acid to the treatment of wounds is not a measure of recent times. In 1859 a powder containing coal-tar was used by M. Démeaux, and its success was communicated to the Académie des Sciences. In the same year Lemaire and Le Beuf used saponaceous emulsion in sloughing and other wounds. Velpeau, however, made an unfavourable report on the practice. The employment of it nevertheless gained ground, and in 1862 the Administration of Civil Hospitals in Paris authorised its use in all the establishments. Lemaire studied its action with considerable care, but expressed some conclusions concerning pus-formation which certainly cannot go uncontested. He considered the formation of pus-globules due to the action of atmospheric air; he compared them to the cells of yeast, and attributed to them an analogous *rôle*. Just as coal-tar prevented fermentation and germination, so it prevented pus-formation. He found that even in recent wounds the application of the coal-tar before the advent of inflammation prevented all suppuration. With the abolition of suppuration the danger of the transmission of purulent infection is done away. In 1860 Lemaire published cases of severe wounds, burns, necroses, and comminuted fractures, which showed the benefits of the treatment. In his work published in 1865, Lemaire recommends the employment of solutions of carbolic acid, varying in strength from 1 in 1000 to 1 in 20 in lotions and on compresses. As, however, the carbolic acid is so rapidly volatilised by the inflammatory heat, Lemaire still inclines to the use of the coal-tar emulsion.

Dr. J. R. Wolfe, of Aberdeen, also used carbolic acid as a dressing for wounds in 1864; he found that cotton wool impregnated with the agent, even when after-

wards dried, was an efficient application. It caused a healthy granulating surface, and counteracted the tendency to hyperplasia and suppuration; and Dr. Wolfe expressed the opinion that its employment for dressing wounds would greatly lessen the risk of purulent and erysipelatous infections in surgical wards.*

When, therefore, Mr. Lister in February, 1867, brought forward his well-known plan of treating compound fractures, abscesses, &c., the principles he adduced were not new. It appears from Mr. Lister's observations that he was at first unaware of the results of M. Lemaire and the striking series of cases published by him as illustrating the effects of the carbolic-acid plan of treatment of suppurating wounds; for he states that he was led to adopt the agent as an antiseptic from observing a remarkable account of its effects upon the sewage of the town of Carlisle. Hence it is probable that the investigators independently working arrived at an identical conclusion. However this may be, to Professor Lister undoubtedly belongs the great merit of having investigated the subject with scientific precision, of having enunciated a system in the treatment of all breaches of surface in which the formation of pus occurs or is imminent. He does not advocate an *agent*, but he establishes a *method*, and all his writings are marked with the earnestness of the real seeker after truth.

Professor Lister taught that the cause of the grave results attendant upon severe external wounds is to the irritation consequent upon the presence of decomposing discharges. The effused products putrefy and by putrefaction assume the properties of acrid irritants. When putrefaction of discharges is prevented, wounds readily heal without suppuration and its attendant dangers. The influence which exercises such power for evil in the cure of wounds, therefore, is putrefaction; and putrefaction, as we have seen in the foregoing pages, is due to the advent to a putrescible material of air containing minute molecules of organised

* Medical Times and Gazette, November 25, 1865.

material. The object of the antiseptic treatment of wounds is to neutralise these molecules, which are the factors of putrefaction, and thus the initiating causes of the various morbid processes which hinge upon it.

The first case recorded by Professor Lister was a compound fracture of the tibia. This was at once treated with carbolic acid and afterwards with its aqueous solution, with the result of an arrest of suppuration and the conversion of the compound into a simple fracture, from which there was prompt recovery. In a second case, also a fracture of the tibia, there was, under the treatment, no suppuration during the period in which it under ordinary circumstances occurs; the external wound nearly healed, and plain water dressing was substituted for the antiseptic. Soon after this was done, however, the occurrence of hospital gangrene in the wound from which the antiseptic influence had been removed rendered amputation necessary. Professor Lister found that pure hydrated carbolic acid was apt to cause some irritation with the formation of a serous exudation; and inasmuch as ordinary coverings like oiled silk or gutta percha, allow a ready escape of the carbolic acid applied, it was thought advisable to protect the first-formed crust (consisting of the effused blood-products incorporated with the antiseptic and the superimposed pad of lint soaked in carbolic acid), with a sheet of tin, and thus to retain the volatile substance in due relation with the effused products. This was accomplished with much success in a third case, and the interesting fact was noted, that portions of the crust formed by the union of the carbolic acid with the effused blood-products had been, in the process of cicatrisation, converted into living tissue. "Thus the blood which had been acted upon by carbolic acid, though greatly altered in physical characters, had not been rendered unsuitable for serving as pabulum for the growing elements of new tissue in its vicinity." In a fourth case (of laceration of the forearm by machinery, in which humerus, ulna, and radius were fractured), the acid was freely applied to the whole interior of the wound and a

splint was adopted. A few minutes afterwards the patient said he was perfectly easy, and a remarkable freedom from constitutional disturbance persisted throughout the case. A most satisfactory cure was accomplished, but the experience taught that strong carbolic acid itself could be over stimulant, and could give rise to suppuration, though this was trifling in amount and productive of no evil consequences. The treatment was successful in a fifth case under circumstances almost desperate. A child of seven suffered a compound fracture of the right leg with frightfully extensive lacerations, the wheel of a crowded omnibus having passed over the limb. It was felt that ordinary methods would be hopeless; nevertheless the case was placed under the carbolic acid treatment. During its progress an unfortunate accident occurred which strangely illustrated the value of the antiseptic plan. A sore upon the leg which had not been treated by the carbolic dressings became attacked with hospital gangrene; wherever the antiseptic crust had covered the parts there was no appearance of hospital gangrene, and perfect granulation was taking place; but the former spread in a frightful way in the unprotected parts, even to the extent of exposing two inches and a half of the tibia, which appeared white as a macerated bone. Nevertheless the bone did not exfoliate; there was little or no suppuration, and ultimately granulations filled the chasm, and the case was converted into one of simple fracture with a granulating sore. In spite of repeated invasions of hospital gangrene there was a perfect recovery, with a limb of the same length as its fellow and of a natural contour. In a sixth case, a labourer, aged fifty-seven, suffered fracture of the thigh bone, the upper fragment being driven through the skin, as well as fracture of the collarbone and severe contusions. The carbolic acid was a *dernier ressort*, for amputation, which seemed the only alternative, would almost infallibly have caused death from shock. Under the antiseptic plan, however, the patient progressed favourably for a fortnight. Suppuration then became manifest; the pus, however, was inodorous, and

seemed due, not to any decomposition from atmospheric influence, but to that form of suppuration which occurs sometimes apart from any external wound. For one week suppuration occurred in diminishing degrees, then it subsided almost absolutely, the patient's constitution seemed unimpaired, and ordinary lotions were substituted for carbolic acid. Subsequently, however, hæmorrhage occurred to which the patient succumbed.*

To continue our sketch of Professor Lister's treatment, we will next turn to his method of dealing with *abscess*. In the class of cases just adduced there is an irregular exposed wound, directly under the influence of the septic matters of the air, and disposed for putrefactive changes. In an unopened abscess there is an accumulation of pus without the agencies of putrefaction. Whilst in the one case it is necessary to destroy, upon the surface of the wound, the septic materials, in the other it is necessary only, whilst evacuating the pus, to prevent the entrance of such agencies with the air as may set up subsequent putrefaction with secondary suppuration and its train of ill consequences. This is done by laying upon the skin, when the incision is to be made, a piece of lint soaked in carbolised oil (one part of acid in four of oil), plunging into the cavity of the abscess a scalpel dipped in the carbolised oil, under cover of the lint, and allowing this latter to fall over the opening thus made as a sort of curtain or valve, which thus permits the egress of the pus, but prevents the ingress of air, except such as is rendered antiseptic by reason of the volatile acid. The next desiderata are to prevent adhesion of the edges of the wound before the pus is perfectly evacuated, and to restrain the decomposition of the stream of pus which in the course of treatment flows from beneath the dressings. Professor Lister accomplished this by spreading a sheet of block tin with carbolised putty, and securing it over the site of the incision, the lowest border being left free for the escape of discharge: the dressing must be changed, according to circumstances, once or twice in the 24 hours, care being taken

* See Lancet, March 16, 23, 30, 1867.

to cover the incision with lint dipped in carbolised oil during the period in which the new dressing is made to take the place of the old. Treated in this way "abscesses of large size have, after the original contents have been evacuated, furnished no further pus whatever, the discharge being merely serum, which, in a few days, has amounted only to a few drops in the 24 hours." At the same time there is the certain absence of all constitutional disturbance. Even when abscesses are associated with caries of bone, the discharge soon ceases to be puriform; when such abscesses remain unopened the caries is necessarily progressive, whereas when opened antiseptically there is "good ground to hope for their steady, though tedious, recovery."* Subsequently, in cases similar to those already cited, Professor Lister found that an aqueous solution of carbolic acid (5 per cent) was as good a primary application as the strong acid, and the putty effectually prevented the subsequent ingress of septic air.

Another application of the antiseptic method in surgery was made by Professor Lister in the operation of *ligature of arteries*. It is well known that tying a large artery in the living body is a perilous operation. Chief among the perils are secondary hæmorrhage, and suppuration with its attendant dangers in the wound made to expose the vessel. When an ordinary ligature is applied to an artery, the internal and middle coats are ruptured, and the external coat is by the constriction rendered into non-vital tissue. The necessary condition induced, under these circumstances, is irritation of the adjacent living structures, chiefly the arterial vessel itself, whose coats, from such cause, tend to degenerate to an imperfect tissue, which, even before further changes, may be insufficient to withstand the shock of the arrested column of blood. Or, by the irritation continuing, suppuration takes place, and, by the degeneration into pus of the de-vitalised structures, the ligature is ultimately set free; but the suppuration which thus liberates the thread is a cause of irritation to the neighbouring wall of the living

* Lancet, July 27, 1867, p. 95.

vessel, and, thus involving it, it may so weaken the barriers that this shall be sufficient to withstand the pulsatile impulse of the heart—hence dangerous or fatal hæmorrhage. Or, inasmuch as suppuration is a necessity of the liberation of ligatures, and is the invariable accompaniment of operations in which they are employed, the evil accidents of suppuration may be manifest, and purulent infection result from the decomposing pus of the wound. Furthermore, there exist all the dangers common to open wounds—erysipelas, gangrenous ulceration, &c. The one danger, then, is irritation, the chief danger suppuration. The reason of such occurrences is the presence of the ligature, and the communication of the wound with the external air. The silk thread necessarily carries with it the materials which the air deposits in its meshes, the organised molecules disposing to putrefactive change. Any substance which contains such molecules will act as an irritant; any substance free from them, or in which they are rendered non-vital (provided the substance itself be non-irritant) will not. If, therefore, the material used to include the artery be rendered antiseptic, and the external wound necessary to expose the vessel be dressed antiseptically, the great dangers of the operation of ligature of vessels may be done away. This has been accomplished by Professor Lister, and the favourable results bear testimony to the soundness of the reasoning.

Professor Lister experimentally tied the carotid artery of a horse with a silk thread steeped in a strong solution of carbolic acid, the incision necessary to expose the vessel being treated on the antiseptic system before described. Healing took place without any suppuration; and on examination of the parts, six weeks afterwards, it was seen that, though a firm adherent clot existed on the cardiac side of the ligature, on the distal side there was no coagulation at all, this having been prevented by the chance circumstance that a large branch was given off close to the ligature, and thus there was a reflex current. Under these circumstances secondary hæmorrhage would infallibly have occurred

if the ordinary irritant ligature had been employed. Prof. Lister next tied the external iliac artery in a lady, on account of aneurism of the upper portion of the femoral; this time he used silk steeped in strong liquefied carbolic acid. Everything progressed well, and there was no suppuration. Ten months afterwards the bursting of another aneurism (of the arch of the aorta) gave an opportunity of post-mortem examination of the antiseptically-ligatured vessel. The artery was found dwindled to a fibrous band, about which, encapsuled, was the knot of the ligature eroded as from partial absorption; around it was a fluid resembling pus, but consisting of fibro-plastic corpuscles, spheroidal cells, and some pus cells. This quasi-purulent secretion could alone, Professor Lister considers, have arisen from the mechanical irritation of the silk. To obviate all chance of such irritation, in future cases, ligatures composed of animal membrane were employed. The carotid of a calf was tied with cat-gut, as well as with strips of peritoneum of an ox, all soaked in saturated aqueous solution of carbolic acid. Thirty days afterwards the animal (in the interval having been in perfect health) was slaughtered, and the parts examined. There was near the vessel no inflammatory thickening. It appeared, at first, that the ligatures existed just as when first applied, but on careful examination it was seen that they had actually become converted into living tissue, just as the carbolised blood had become organised in cases of antiseptic treatment of wounds of the surface. "The two pieces of cat-gut which had been tied round the vessel at that part had become, as it were, fused into a single fleshy band, inseparably blended with the external coat of the artery." "It appears, then, that by applying a ligature of animal tissue antiseptically upon an artery, whether tightly or gently, we virtually surround it with a ring of living tissue, and strengthen the vessel where we obstruct it." * The best material to employ, according to Professor Lister's matured

* "Observations on Ligature of Arteries on the Antiseptic System," by JOSEPH LISTER, F.R.S. From the Lancet, April 3, 1869. Corrected February, 1870. Edinburgh: Edmonston & Douglas. London: Churchill.

opinion, is cat-gut suspended in a mixture of five parts of olive, or linseed, oil with one part of carbolic acid liquefied by the aid of water. The presence of water is necessary for the satisfactory condition of the ligatures, and soaking should take place for a few weeks.

A further experience, besides corroborating the success of the general plan, enabled Professor Lister to attain a greater uniformity of good results by improvements in matters of detail. It was found that the method might be practised in cases which might *à priori* appear unsuitable. An interesting case is narrated by Professor Lister of a penetrating wound of the thorax and abdomen, in which death from hæmorrhage was imminent, and a piece of omentum five inches long protruded from the external opening. Mr. Cameron cut off the protruded portion of omentum, and plugged the wound with lint dipped in carbolised oil, passing the strips in every direction into the pleural cavity as far as possible. Instead of the carbolic acid being an irritant to the lung, it is the converse, inasmuch as it prevents putrefaction, which is one of the worst forms of irritation. The external wound was then covered by carbolised putty. The following day the plugs were withdrawn, the use of the putty being continued. Although blood was copiously effused into the pleura, and air existed in relation with it, there was no decomposition, the air being sufficiently carbolised, and that inspired by the ordinary passages, being robbed of its putrefaction-inducing property by its filtration through the lung tissue. The patient was free from all symptoms of irritation; there was no pus; and he made an admirable recovery. A case is also recorded by Professor Lister of compound fracture of the leg and wound of the left foot in a woman of 74 years of age, which showed the advantages of the antiseptic plan. The open wounds of the fracture granulated with no more disturbance, local or constitutional, than as if the fracture had been a simple one; as regards the wound in the foot it rapidly cicatrised, "complete healing by scabbing," Professor Lister writes, "having occurred in, I suppose, the largest wound ever known to

heal in that manner in the human subject." In these and analogous cases experience showed that certain fallacies and dangers attended the application of antiseptic dressings as heretofore adopted. If the antiseptic material be conveyed by means of lint soaked therewith, there is a danger on account of the porousness of the imbibing material that the albuminous discharges from the wound that it necessarily absorbs may displace the antiseptic, and thus a channel may be established with the external air and its septic agencies. The putty, spread upon an impermeable material, is more efficacious than lint dressings, but it is neither so handy nor so cleanly. Professor Lister tried and recommended as thoroughly reliable lead plaster mixed with one-fourth part of bees'-wax to give it sufficient consistence, and carbolic acid in the proportion of about one-tenth of the whole. The usual plan now adopted was to make a permanent antiseptic dressing by applying—(1) two or three layers of lint soaked in carbolised oil, overlapping the wound; (2) a piece of oiled calico covering the whole, and extending beyond the area of the lint; (3) a stratum of carbolised putty spread on calico. The plaster just mentioned, though a good external guard, was unfitted as a permanent dressing, because it became softened by the carbolised oil beneath it. The most satisfactory material proved, however, to be a plaster composed of shellac and carbolic acid spread upon calico: such a plaster retains the carbolic acid with much tenacity, fails to irritate the skin, and is impermeable alike to water and to oil. Its only disadvantage was its tendency to stick to the skin, which was obviated by covering it with a thin film of gutta percha, by brushing over its surface a solution of the latter in bisulphide of carbon. In some cases (permanent dressing for example) this adhesiveness is a positive gain, and then the film of gutta percha must be got rid of by friction and brushing the surface with liquid carbolic acid. For a dressing that is to be periodically changed, the non-adhesiveness is a valuable quality.*

More lately Professor Lister has recorded a case, which

* British Medical Journal, November 14, 1868.

illustrates the value of the antiseptic method, and the details which his experience has led him to adopt. A man was admitted under Professor Lister with compound dislocation of the ankle. Not only, as is well known, has this injury usually been treated by amputation, but it is very fatal, fourteen consecutive cases died in the Edinburgh Infirmary according to the late Professor Syme. The dislocation was reduced with some removal of bone; watery solution (5 per cent) of carbolic acid was well syringed into the joint, and the skin in the neighbourhood was well washed with it; lac-plaster was wrapped in two layers round the limb, extending well up the leg, and embracing heel and instep; a cloth to absorb the discharges percolating from beneath the margins of the plaster was bandaged on, and a splint was applied. At the same time, in the same patient, a severe scalp-wound was treated in like manner, with the addition of the approximation of the edges by sutures of silk steeped in carbolised bees'-wax (1 in 10). Furthermore, a compound fracture of the elbow joint was treated in the same way. The dressings were changed on the day following, danger of the entry of septic air being avoided by cautiously syringing a weak solution of carbolic acid (1 to 40) beneath the margin of the lac-plaster, and continuing to do so as this was elevated, examination of the wound being made as it was thus flushed with the antiseptic lotion. Subsequent dressings differed from the first in this wise—the wound itself was covered by a layer of material destined to protect it from the irritant effects of the carbolic acid in the antiseptic stratum. All that a wound needs for successful healing is to be protected from dangers imported from without. This accomplished, it should simply be let alone. The septic dangers of the air are the chief and the most subtle. The "protective" should be unstimulating, impervious to carbolic acid, insoluble in the discharges, and accurately adapted to the wounded part. A good material has been suggested by Dr. Coats; oiled silk is brushed over with a mixture of dextrine (1 part), powdered starch (2 parts), and strong aqueous solution of carbolic acid (16 parts). This material becomes uniformly

moistened when dipped in carbolised water, and when applied in two layers it pretty effectually intercepts the advent of any irritant carbolic acid from the external antiseptic covering to the young and tender granulations of the healing wound. As the discharge diminishes, the intervals of dressing may be prolonged from once in 24 hours to once a week. The presence of the "protective" greatly diminishes the copiousness of the discharge by witholding all abnormal stimulus. In the case quoted, the wound healed without the production of a trace of pus. The intervals of the dressings were from the date of the accident—(*a*) 1 day; (*b*) 1 day; (*c*) 2 days; (*d*) 3 days; (*e*) 3 days; (*f*) 5 days; (*g*) 5 days; (*h*) 7 days; (*i*) 8 days. Six weeks after the accident the ankle-fracture healed with the foot in good position, and with satisfactory motion in the joint. The compound fracture into the elbow joint was healed, and the splint discarded in 5 weeks from the injury, and all the other wounds healed without the formation of a drop of pus.*

Effects of the Antiseptic Method in Surgery upon General Salubrity.—As Professor Lister has pointed out, the advantages of the antiseptic method in surgery are not confined to the immediate induction of plastic union in the wounded parts. Its effects are manifest upon the general salubrity of a surgical hospital. The hygienic dangers to which a patient who has undergone a surgical operation is subject are threefold. There is the danger of the influence of special septic agencies from without which are prone to engender special diseases of infection; there is the peril arising from the decomposition of discharges and the absorption into the patient's system of the infecting poison derived from his own wounds; and lastly, there is the danger of those infecting materials generated in one patient being centrifugally diffused to other patients in his neighbourhood. The antiseptic method which prevents putrefactive decomposition in the individual wound renders the production of

* Remarks on a Case of Compound Dislocation of the Ankle, &c., by Professor LISTER, F.R.S. Edinburgh: Edmonston and Douglas, 1870.

a disseminable poison impossible, and makes any inoculable septic agency which may by any chance come into relation with the absorbent surface of a wound at once inert.

Touching the effects of the antiseptic system of treatment upon the salubrity of a surgical hospital, Professor Lister records the following observations. Its results, Professor Lister says, "upon the wards lately under my care in the Glasgow Royal Infirmary, were in the highest degree beneficial, converting them from some of the most unhealthy in the kingdom into models of healthiness." The evidence is peculiarly circumstantial. The Glasgow Infirmary is structurally spacious and apparently well fitted for its purpose, yet it proved extremely unhealthy; pyæmia, hospital gangrene, and erysipelas being rife within it. Occasionally such a crisis occurred as to render necessary the complete closure of individual wards. A light was cast upon the cause of this unhealthiness, when an excavation made close to a ward evacuated on account of its unhealthy character, disclosed a place of sepulture for numbers of persons who suffered in the cholera epidemic of 1849. Furthermore, one end of the building was conterminous with a churchyard wherein multitudes of the corpses of paupers had been buried in pits. Surrounded by these foci of infection, Professor Lister's wards, in which the antiseptic system was practised, were free for three years from the infecting diseases which constitute the ordinary evils of surgical hospitals. Moreover, in his own individual experience, Professor Lister found a marked difference in the results of amputations before and after the period at which antiseptic dressings were commenced. The following is a summary of the statistics:—

Before the antiseptic period (35 cases), one death in 2 1-5 cases.

During the antiseptic period (40 cases), one death in 6 2-3 cases.*

* See pamphlet "On the Effects of the Antiseptic System of Treatment upon the Salubrity of a Surgical Hospital," by Professor LISTER, F.R.S. Edinburgh: Edmonston and Douglas, 1870.

It should be borne in mind that the antiseptic method as applied in this period was not perfect, but was gradually improved, as we have been just considering. Much testimony has followed that of Professor Lister, to the effect that the antiseptic method has promoted the general salubrity of a hospital. The very infirmary which served as the text of these remarks, has given evidence that by the adoption of this method a great amelioration has been obtained.* In Berlin the evidence of Professors Bardeleben and Langebeck confirms the views of Professor Lister.† A very important corroboration of Professor Lister's views comes from Professor Saxtorph, of Copenhagen. In a letter to Professor Lister, the latter says, "The hospital to which I am appointed head surgeon (the Frederik's Hospital), is a very old building—in fact, it is now much more than a hundred years old—and it contains about 350 medical and surgical beds. In the surgical wards I have room for about 150 patients, but the usual number during the winter has varied from 100 to 130. Formerly there used to be every year several cases of death caused by hospital diseases, especially by pyæmia, sometimes arising from the most trivial injuries. Now I have the satisfaction that not a single case of pyæmia has occurred since I came home last year, which result is certainly owing to the introduction of your antiseptic treatment." ‡ The good results of the antiseptic plan of treatment are attested as well by the intrinsic evidence of the cases related by Professor Lister as by other most competent witnesses; the practice was followed with more or less attention to detail, the preparations of carbolic acid being used in all. The following, amongst many others, have recorded details of success :—Dr. Wolfe, of Aberdeen, employed it in wounds and compound fractures ;|| Mr. Wood, of King's College, combined with it the use of chloride of zinc ;§ Dr. Rose, of Kidderminster, used it in compound

* See Brit. Med. Journal, April 9, 1870, p. 361.

† *Ibid.*, May 28, 1870, p. 557.

‡ Lancet, August 27, 1870, p. 287.

|| *Ibid.*, Sept. 28, 1867, p. 410.

§ *Ibid.*, Oct. 12, 1867, p. 455.

fractures, burns, and wounds;* Maisonneuve testified to the success of aqueous solution of carbolic acid for wounds;† Mr. Witten, of York, a case in which carbolised oil was used for a severe machinery accident;‡ Mr. Lund, use of carbolised oil; || Dr. Bernard, R.N., records examples of extraordinary success in the treatment of wounds and performance of operations, including deligation of arteries, on Mr. Lister's plan; § the late Professor Symes strongly advocated the method,¶ and adduced cases of compound fracture, wounds, and abscesses successfully treated;** Dr. Hamilton, of Canonbury, recorded the rapid cure of a case of acute synovitis of the knee under carbolic putty spread on lead foil; †† Mr. C. Heath, a case of psoas (?) abscess, antiseptically opened and treated with carbolic acid; ‡‡ Mr. Maunder, antiseptic ligature of arteries; |||| Mr. Tyrrell, Dublin, employment of carbolised oil; §§ Mr. Hamilton, Liverpool, the treatment in wounds, fractures, abscesses, and operations; ¶¶ Dr. Kelburne King, of Hull, the plan advocated by Lister, in wounds, abscesses, operations;*** Mr. Hancock, of Charing Cross Hospital, endorsed the treatment;††† Mr. Fleischmann detailed a severe scalp wound treated by carbolic acid;‡‡‡ Dr. Geo. H. Pringle, of Paramatta, cure of gunshot wound treated by carbolic putty spread on sheet lead; |||||| Dr. Marson found the application of carbolic acid valuable in fœtid sloughing ulcers in China (Takao, Formosa); §§§ Dr.

* Lancet, Jan. 16, 1867, p. 89.
† Brit. Med. Journal, Oct. 5, 1867, p. 305.
‡ *Ibid.*, Nov. 23, 1867, p. 472.
|| *Ibid.*, Dec. 14, 1867, p. 556.
§ Appendix to Statistical Report of Navy, 1867.
¶ Lancet, July 6, 1867.
** Brit. Med. Journal, Jan. 4, 1868, p. 1.
†† Lancet, July 11, 1868, p. 40.
‡‡ Med. Times and Gazette, July 4, 1868, p. 5.
|||| Lancet, Nov. 7, 1868, p. 596.
§§ Brit. Med. Journal, Jan. 18, 1868, p. 53.
¶¶ *Ibid.*, April 28, 1868, p. 413.
*** *Ibid.*, Dec. 5, 1868.
††† *Ibid.*, p. 597.
‡‡‡ *Ibid.*, Sept. 26, 1868, p. 336.
|||||| *Ibid.*, April 25, 1868, p. 406.
§§§ *Ibid.*, Dec. 26, 1868, p. 665.

Joseph, of Leipsic, abundantly confirmed Lister's good results in the surgical clinic of Jacob's Hospital;* similar testimony came from Dresden, and from Professor Dittell, of Vienna;† Mr. Bickersteth, of Liverpool, cited experience of the value of the treatment in wounds, in ligature of arteries; ‡ Dr. Rose, of Kidderminster, in cases of wounds, fractures, and burns; || Mr. Maunder, at London Hospital, antiseptic ligature of arteries; § Mr. Berkeley Hill endorsed Lister's plan.¶ A case of successful healing of a fistulous opening at the umbilicus, forming an abnormal anus, under the care of Dr. Sieveking, of St. Mary's Hospital, is recorded.** The plan was tried with more or less of completeness in the hospitals of London, and there was much, though not unreserved, evidence of success. The experience of University College was largely in its favour; not only were surgical results successful, but pyrexia after operations was notably reduced under the plan of dressing; pyæmia, which had existed up to the commencement of the plan, ceased, and no erysipelas occurred; but it was noted that vomiting was an effect of the dressings.†† Mr. Holt used the treatment with success at Westminster Hospital. It was partially employed at the Great Northern Hospital, where it was said that the most notable point under its employment was the absence of pyæmia. At the London Hospital Mr. Cowper employed it with great success in severe operations and injuries.‡‡ Mr. Dobson, of Bristol; |||| Mr. Swain, of Devonport; §§ Dr. Bartleet, of Birmingham; ¶¶ Mr.

* Practitioner, July, 1868, p. 62.

† *Ibid.*, August, 1868, p. 129.

‡ Lancet, May 29, 1869, p. 743, and *Ibid.*, p. 811, and July 2, 1870, p. 6.

|| *Ibid.*, Jan. 16, 1869, p. 89.

§ *Ibid.*, Jan. 23, 1869, p. 122.

¶ Brit. Med. Journal, Jan. 22, 1869, p. 81.

** *Ibid.*, Jan. 16, 1869, p. 48.

†† Med. Times and Gazette, Dec. 5, 1868, p. 641; ditto, March 20, 1869; Lancet, Jan. 16, 1869, p. 86.

‡‡ Med. Times and Gazette, July 9, 1870, p. 34; ditto, Nov. 14, 1870, p. 587; and Dec. 10, 1870, p. 670.

|||| Brit. Med. Journal, Feb. 13, 1869, p. 151.

§§ *Ibid.*, p. 164.

¶¶ *Ibid.*, March 27, 1869, p. 284.

Pridgin Teale, of Leeds :* Dr. Keith, Edinburgh ; † relate cases showing the success of the treatment. Dr. Cleborn, of the United States, employed carbolic acid in boils, whitlows, and abscesses.‡ Dr. H. B. Spencer, of Oxford, recorded a case of paracentesis thoracis dressed with carbolised oil.|| Mr. Gravely (Newick) a case in which a foot was saved from amputation by dressing with the oil.§ Mr. Lund recorded instances of success under the antiseptic treatment, and advocated the use of antiseptic (carbolised) cere cloth as a substitute for the lac plaster.¶ Mr. Gutteridge obtained excellent results in compound fractures, wounds, and burns, using carbolised oil and sheet lead.** Dr. Rose, of Chesterfield, in hand laceration ; †† Mr. Worthington ; ‡‡ Mr. Jessop, of Leeds ; |||| Dr. A. Marshall, of Preston ; §§ Dr. Morris, of Barnsley ; ¶¶ Dr. James Shore ; *** Dr. George A. Turner, of Samoa, South Sea Islands, (using carbolised oil and sheet lead) ; ††† adduced instances showing great success in employment of the antiseptic plan. So also did Dr. McCoy, of Sierra Leone.‡‡‡ In the war between France and Prussia, the carbolic applications have been largely adopted and their value recognised.||||||

The evidence adduced leaves no possibility of doubt that the application of the antiseptic method of treatment in

* Brit. Med. Journal, Aug. 28, 1869, p. 256.

† *Ibid.*, Sept., 18, 1869, p. 336.

‡ *Ibid.*, Feb. 20, 1869, p. 164.

|| *Ibid.*, June 12, 1869, p. 535.

§ *Ibid.*, Jan 1, 1870, p. 21.

¶ *Ibid.*, Sept. 4, 1869, p. 267.

** Lancet, Nov. 20, 1869, p. 704.

†† *Ibid.*, June 4, 1870, p. 825.

‡‡ *Ibid.*, June 25, p. 922.

|||| Brit. Med. Journal, Oct. 15, 1870, p. 412.

§§ *Ibid.*, Oct. 29, 1870, p. 457.

¶¶ Lancet, Nov. 19, 1870, p. 703.

*** *Ibid.*, Dec. 17, 1870, p. 845.

††† Lancet, July 23, 1870, p. 114.

‡‡‡ Med. Times and Gazette, Oct. 24, 1868, p. 492.

|||||| Brit. Med. Journal, Sept. 17, 1870, p. 317 ; Oct. 8, 1870, p. 398 ; Dec. 10, 1870, p. 638 ; Practitioner, Nov. 1870, p. 292.

surgery has been successful, and there are results attending it which place it upon a different level to that attained by any other method of treatment hitherto put in force; these are the facts that severe and extensive wounds can heal without the production of pus, and that the dangers of pyæmia and surgical infective diseases usually attendant in greater or less degree upon surgical operations, can be absolutely put away.

Still there are adverse opinions concerning the treatment; some have failed to attain the success which so many have recorded. It must be acknowledged that this non-success *may* really depend on an imperfect application of the means. Others have endeavoured to explain the success which they acknowledge to be attained on other grounds than those adduced by Lemaire, Lister, and those who follow their teaching. A definite idea concerning the *rationale* of the operation of a given agent can alone lead to a satisfactory and discriminating employment of it. In nothing more than in the application of the antiseptic method is a half-knowledge dangerous to the practitioner. We will proceed to consider briefly the basis on which the plan is founded, and the practical details which result from the data already adduced.

CHAPTER XXIII.

PRINCIPLES OF THE ANTISEPTIC SYSTEM IN THE TREATMENT OF WOUNDS.

Relation between Putrefaction and Suppuration.—It appears to me that a great deal of the scepticism with which many have received the enunciation of the theories upon which the antiseptic system in surgery is based, has arisen from a wrong conception of the relation between the suppurating process and the conditions of putrefaction.

Many who acknowledge that the results of the treatment have been very valuable, refuse to believe in the theory of septic germs. The danger of this scepticism is that they neglect the minute precautions which a belief in the theory enjoins; and thus both theory and practice are charged with errors not their own. The occurrence of this scepticism is very pardonable, for the relation of the germ theory to the evils proximate and remote of wounds, have, even by advocates of the germ theory, been stated with crudeness and want of lucidity and decision. Those who see the antiseptic method in operation, who witness the undoubted fact that large wounds treated by carbolic acid can heal without the production of a drop of matter, may yet fail to see by what faculty the agent exerts this power of preventing pus-formation. Being told that it is a potent destroyer of germs, they enquire, "How do these germs induce suppuration, and what is their relation to the product, pus? Am I to believe that the rudiments of pus-cells are floating in the air, and that these finding a suitable soil on the living animal body, develope and propagate as pus-cells?" This view was gravely put forward by Lemaire. According to him the formation of pus-globules is due to atmospheric air. He compared them to the globules of yeast, and attributed to them an analogous *rôle* and an identical origin.* It must be seen that such a view cannot be maintained, for we have abundant facts to show that the formation and concentration of pus can take place in situations to which atmospheric air cannot penetrate, and observations upon pus-corpuscles show that they have no such mode of origin as this which has been claimed for them.

Those observers who have closely watched the development of the pus-corpuscle, though they are divergent in their views of its proximate origin, nevertheless all agree that it is derived from the intrinsic structures of the body and not from material imported from without. At the pre-

* Je les ai comparés aux globules de la lévure de bière, et leur ai attribué un rôle analogue et la même origine."—De l'Acide Phénique, p. 20.

sent time the theories as to the immediate production of pus may be described as three :—First, that of Virchow, which considers that pus is formed alone from the cells of the connective tissues and of epithelium ; second, that of Cohnheim, that pus-cells are white blood corpuscles which have emigrated from the blood stream through the walls of capillaries ; third, that of Beale, that pus is a form of germinal matter capable of being evolved from *any* of the tissues. Dr. Beale has adduced so many arguments derived from his own patient investigations that the probabilities seem largely in favour of the view which he has advanced.

When from any cause there is retardation of blood in a capillary, the number of the white blood-corpuscles increases, partly from arrest of those normally contained in the blood-stream, partly from rapid multiplication of those which have been arrested. The capillary becomes distended and its walls attenuated and lacerated, and through the lacerations pass minute particles of germinal matter. When outside the capillary these minute particles rapidly develope and multiply. They are "the *descendants* of white blood corpuscles, but they are not the white blood corpuscles *themselves* which were previously in the blood, and which were circulating in that fluid. They may continue to grow and multiply like other kinds of germinal matter, until at last that rapidly growing form of bioplasm, the common result of the greatly increased growth and multiplication of every form of bioplasm in the living body, may be produced. Thus the *pus-corpuscle* may be a descendant of the white blood corpuscle as well as of the germinal matter of epithelium and of other tissues; and we may trace back its parentage to the original embryonic bioplasmic mass which must be regarded as the primitive ancestor of all."* The initial change inducing this series of actions is one of nutrition; any tissue which is supplied with pabulum in excess can proceed through the various stages

* BEALE, Quarterly Journal of Microscopical Science, Vol. x., New Series, p. 225.

of degradation to pus. The great histological characteristic of the pus-corpuscle is its observed motional activity (see Fig. 42); the soft material of which the corpuscle is composed becomes protruded at various points of its circumference in different degrees, causing it to assume ever-changing shapes. This movement closely resembles that of an independent individual organism, the *Amœba*. The buds and offshoots from the motile pus-corpuscle become detached from it to form individual corpuscles, which rapidly live, grow, and develope like their parent.

The first inducing cause of pus formation may be preliminarily defined as IRRITATION. Such irritation may be brought about by agents operating primarily either upon the tissues or upon the nervous system. The effect of such irritation depends upon its degree; there may be congestion, exudation, granulation, with, after interruption of the normal functions of the part, an increase of the *formative* activities of the protoplasmic masses subject to the condition of irritation. Or the irritation being in excess, congestion and exudation may pass on to rapid cell-proliferation and suppuration, "the pus-cells being the extreme of excess of quantity and impairment of quality in the product of abnormally excited nutrition."*

The great property which differentiates *pus* from the normal cells or protoplasmic masses which constitute the various parts of the healthy organism, is its property of rapid development and self-multiplication. No longer are these living molecules subservient to the nutritive needs of the higher organism which contains them; they live a life of their own, antagonistic to the life of the containing organism. The view which I have thus propounded is quite consonant with the views of those who believe that in inflammation there is a degradation, not an exaltation, of the powers of life. In the early stages of inflammation there is a local withdrawal of the *vis nervosa* which controls

* LISTER, pamphlet, On a Case of Compound Dislocation of the Ankle, &c., p. 21. See also, "On the Early Stages of Inflammation."—Philosophical Transactions, 1858.

the normal circulation; there is stagnation of the blood-stream. By continuance of the retrograde process there is further abstraction of force from the higher organism by transference of vital power to the molecules effused from the inflamed part: *pari passu* with the vital acts, the development and proliferation of the latter is the vital depression of the former.

Under different circumstances and in different situations pus-cells possess varying powers of proliferation. The germinal matter of pus has differing potentiality. The protoplasmic matter of which it is composed, at first soft and diffluent, rapidly shooting forth its bud-processes, may become denser, on its exterior a cell-wall may be formed; then as this cell-wall becomes denser, the power of budding and reproduction ceases, and the cell-contents undergo retrograde metamorphosis into oil globules and inorganic matter.

Pus, then, is the product of the degraded germinal matter of an organism, and its formation is due to any local irritation which reaches a certain intensity. There are many varieties of irritation which can induce suppuration. Direct violence we know will induce it even when the skin is unbroken, and there is no possible influx of germ-laden air. Local disorders of innervation can induce it. Stimuli, physical and chemical, can induce it. It is a matter of common observation that chemical agents, as caustics, cause the production of pus. Moreover, the very agents which are employed as antiseptics possess this power. Carbolic acid itself will cause irritation and pus-formation. It is clear, therefore, that not only is an antiseptic not necessarily a preventive of suppuration, but it can itself induce suppuration. The one fact that we arrived at is, that *the cause* of suppuration is *irritation*. Anything which can sufficiently subdue the irritation which induces it can necessarily suppress suppuration. Whilst, therefore, the idea of the direct influence of atmospheric germs as inducing suppuration is effectually disposed of, it may yet be that the irritation arising from the putrefaction of wounds is a potent cause

of the suppuration which occurs in them. Thus, atmospheric germs, though not the direct, may yet be the chief causes. To investigate this, we will briefly consider *the changes which occur in wounds of the surface.* The first occurrences are laceration of the tissues, effusion of blood, exudation from the lacerated surfaces, and admission of air. Provided the lacerated parts be brought together within a short period of the injury in such manner that no atmospheric air is enclosed in any pouch of the torn tissues, nor any foreign irritant material interposes between the surfaces, healing takes place by first intention. The fluid effused from the cut surfaces is non-irritant; the blood-products are absorbed, and the molecules of living material which develope and proliferate are plastic, *i.e.*, they become converted into the matured tissues of the healthy animal.

If the wounded surfaces, however, remain in contact with atmospheric air other changes ensue. Some of these are chemical, some vital. The first chemical change noted is oxidation. Supposing the wound has involved a muscle, the following occurs, as has been pointed out by Dr. B. W. Richardson.* The normal alkaline fluid of the muscles becomes acid: this change may occur in 3 or 4 minutes; it is hastened by warmth and moisture of the air, or by the presence of organic impurity in it; it is retarded by dryness and cold. "Just as blood oxidises in the lung, so this intestitial fluid oxidises when it is exposed to the atmospheric oxygen." This acidity may be a source of irritation to the wounded tissue, and the oxidation may be manifested in destruction of tissue. It is, however, clear that mere acidity of the fluid is not the cause of unhealthiness of wounds or retardation of their healing, for we well know that dressings of acid reaction (notably sulphurous acid) have tended to a prevention of suppuration and a rapid cicatrisation.

The occurrence of putrefaction in an open wound is a matter of certain knowledge. It is obvious that the con-

* See Medical Times and Gazette, April 13 and 20, 1867, pp. 383 and 409.

ditions necessary for such a process are present in a high degree. The surface of the wound in contact with the air exhibits some of the most putrescible fluids known—blood and albuminous exudations: moisture is necessarily present, and the heat of the parts is such as to dispose to a rapid series of changes. All conditions are united for the induction of the process of putrefaction as we have formerly considered it. There is not merely an *à priori* likelihood of putrefaction occurring, but an impossibility that it should fail to occur under these conditions. And the fact is easily demonstrated. "It may be ascertained as a matter of observation that, in a compound fracture, 24 hours after the accident, the coloured serum which oozes from the wound is already distinctly tainted with the odour of decomposition, and during the next two or three days before suppuration has set in the smell of the effused fluids becomes more and more offensive."* The question occurs—in how far is this undoubted putrefaction a source of delay and danger in the healing of wounds? It is scarcely necessary to urge that it is a source of danger: every one knows that a fœtid condition of a wound is an adverse, whilst a clean and inodorous condition is a favourable, sign. This fœtid condition is but the indication of the putrefaction which is occurring. Wherever there is this putrefactive condition of a wound, it is a matter of common observation that there is irritation—irritation manifested not only in the exposed tissues of the wound, but in the system of the individual subject to the injury. Conversely, when the wound is kept free from putrefaction, provided always there be no other source of irritation, there are no signs of danger local or general. Fractures of the bones, when the skin is unbroken, heal without suppuration and are entirely free from the dangers attendant upon wounds which are in contact with the air. Under certain circumstances, the exudation from a recent wound will dry and form a scab; this serves as a natural

* LISTER, "On a New Method of Treating Compound Fracture, Abscess," &c.—Lancet, March 16, 1867, p. 326.

method of exclusion of air from the wound; healing goes on beneath the scab just as if air had not been admitted at all. Thus, as was shown by John Hunter, in a compound fracture in which the external opening was sufficiently small to be completely sealed by the natural crust, healing would take place just as in a simple fracture. The results of subcutaneous surgery have shown how extensive wounds will heal without any of the dangers which attend wounds of the surface. Mr. Wm. Adams has shown some admirable examples of formidable operations performed by the subcutaneous method with excellent results.

Everyone knows the danger which attends the admission of air into the great serous cavities of the body. How many contrivances have been effected for guarding against this contingency! Fluids may be withdrawn from these cavities, and yet there follow no irritation, no suppuration; but let air be admitted, and there ensues a definite series of changes, irritation of the general system, suppuration, and finally decomposition of pus, with fœtor and the usual signs of putrescence.

There is much evidence to be added. We have seen that the condition of putrefaction can be a condition of irritation in a wound, and that the absence of the chief condition of putrefaction, the admission of atmospheric air, is a cause of the prevention of such irritation. But we have evidence that other restrictive influences upon putrefaction have also a power of checking the phenomena of irritation in wounds. A great necessity for putrefaction is the presence of water; without moisture it cannot occur. "In the battle-fields of Egypt," says Dr. B. W. Richardson, "operations performed under canvas in perfectly dry heated air, in which all decomposition of albuminous matter is impossible—in which air, in fact, albumen itself dries into a horny covering—the process of rapid healing was a marvel to all who witnessed it."*

We have, therefore, a mass of evidence showing that

* See Medical Times and Gazette, April 13 and 20, 1867, pp. 383 and 409.

putrefaction necessarily takes place in wounds which remain in contact with the air, and that this putrefaction is capable of initiating phenomena of irritation which do not exist when it is prevented.

The irritation arising need not amount to that degree which is necessary for the induction of suppuration. For this the element of time is necessary; granulation can take place with little or no suppuration even in the presence of putrefaction. Suppuration only takes place in an open wound under the irritant influence of the putrefactive process when prolonged for 3 or 4 days; just as it is induced by internal inflammatory stimuli, not immediately, but after the lapse of time and the occurrence of various cycles of changes. Yet putrefaction is none the less a most potent inducer of suppuration as of the other phenomena of irritation. Its influence far exceeds in this direction that of which we have been accustomed to think far more potent—foreign bodies for example. Has it not been generally understood that a piece of detached and dead bone is an irritant body, which must set up suppuration around itself, and eventually construct, by the breaking down of the neighbouring soft parts, a channel whence it can become discharged from the organism? But Professor Lister records a case "in which an extensive portion of the shaft of the tibia had lost its vitality, and lay exposed in a large granulating sore. The granulations grew up and enclosed the dead bone, which, being prevented from putrefaction by the treatment employed, was destitute of the usual acrid properties of an exfoliation; so that the granulations being not stimulated by it, not only formed no pus from the surface in contact with it, but gradually consumed the dead mass by absorption."*

From all sides, then, I consider the evidence supports the statement of Professor Lister with regard to wounds that, of all external agencies, the most injurious by far is putrefaction."

In the former pages we have discussed the nature of

* Remarks on a Case of Compound Dislocation of the Ankle, &c., p. 22.

putrefaction. We have concluded that it essentially depends, not upon the atmospheric air itself, but upon life-possessing particles suspended in it. To prevent the evil influences of wounds, therefore, it is not of absolute necessity to exclude atmospheric air, but to exclude or annul those molecules on which its putrefaction-inducing properties depend.

A synthetical illustration of the truth of this doctrine is adduced by Professor Lister, in reference to pneumothorax with emphysema, resulting from puncture of the lung by a fractured rib. He says :—

"A beautiful illustration of this doctrine seems to me to be prevented in surgery by pneumothorax with emphysema, resulting from puncture of the lung by a fractured rib. Here, though atmospheric air is perpetually introduced into the pleura in great abundance, no inflammatory disturbance supervenes; whereas an external wound penetrating the chest, if it remains open, infallibly causes dangerous suppurative pleurisy. In the latter case the blood and serum poured out into the pleural cavity as an immediate consequence of the injury are decomposed by the germs that enter with the air, and then operate as a powerful irritant upon the serous membrane. But in case of puncture of the lung without external wound, the atmospheric gases are filtered of the causes of decomposition before they enter the pleura, by passing through the bronchial tubes, which, by their small size, their tortuous course, their mucous secretion, and ciliated epithelial lining, seem to be specially designed to arrest all solid particles in the air inhaled. Consequently the effused fluids retain their original characters unimpaired, and are speedily absorbed by the unirritated pleura."*

A further synthetical proof of the doctrine is the success which has attended the practice of the principles which Professor Lister has enunciated. In using carbolic acid an agent is employed which arrests putrefaction ; where putrefaction is thus arrested, the healing of wounds takes place

* Lancet, March 16, 1867.

without suppuration and without symptoms of irritation, either in the wound or in the general system.

I trust that I have been able to express to the reader the relation which logically subsists between putrefaction and suppuration. Putrefaction is one of the many forms of irritation that can induce the formation of pus. In the case of open wounds it is the chief of such forms of irritation. In open wounds, suppuration is often an evil and never a necessity. Therefore the prevention of putrefaction in wounds is certainly to be attempted.

The relation between suppuration and atmospheric germs is this :—The germs alone existing in the atmosphere render it capable of inducing the putrefaction which is the chief source of irritation and suppuration in wounds. Imported by the air or by any other physical medium, as water, foreign bodies, &c., to the eminently-putrescible material of the surface of wounds, these germs can initiate putrefaction and its attendant phenomena just as they can, under other circumstances, the fermentations and putrefactions which we have considered before. When, however, these germs are robbed of their vital properties by an agent, whether in the air or in the fluid, which is a poison to them, they are incapable of initiating putrefaction and its attendant dangers, irritation and suppuration.

The bases of the antiseptic treatment of wounds may be thus defined :—

A. Suppuration is an unmitigated evil; it is in no sense necessary for the healing of wounds. It is injurious (1) to the individual, *directly*, by withdrawing force which under normal conditions is subservient to the nutritive needs of the organism; *indirectly*, by the liability of pus to decompose and give rise to an infectious disease-producing material, which may be re-absorbed; (2) to the community, by being capable of conversion into the transmissible virus of spreading disease.

B. Whilst any irritation of sufficient intensity can induce suppuration in the case of external wounds, putrefaction is the chief; and anything which prevents

putrefaction in an open wound tends to prevent suppuration.

C. The object of the antiseptic system is to prevent putrefaction, and thus to prevent the evils which flow from it.

CHAPTER XXIV.

THE ANTISEPTIC METHOD IN SURGICAL PRACTICE.

The idea that the antiseptic method of treatment is of necessity the carbolic acid method of treatment must from the very first be discarded. Carbolic acid holds a very high place as an antiseptic, and practice has proved it to be of great value, but it is far from being the only agent to be employed: it is inferior under certain conditions, as has been already pointed out, to other substances which possess antiseptic qualities, and it possesses qualities besides those attaching to it as a preventive of putrefaction which sometimes antagonise its advantages. Many of the materials which have been employed from the most ancient times vie with carbolic acid in their antiseptic power. The antiseptic system in no wise asserts that the old lights are all to pale before the new.

"Vixere fortes ante Agamemnona."

The great lesson it would teach is that of methodic discrimination according to fixed and definite indications. Professor Lister has, I know, been cited as the champion of carbolic acid, but, as well from carefully reading his works as from observing his practice in the Edinburgh Infirmary, and enjoying his own exposition of his own views, I am sure the inference of those who thus style him is a false one. In his practice Professor Lister employs many antiseptics besides carbolic acid as the chief.

We will now consider the best means of practically following the theoretical indications in the case of *wounds of the surface.*

In the treatment of such injuries after the antiseptic plan there are two objects:—(*a*) to destroy the putrefactive elements upon the fluids of the exposed surfaces of the wound; (*b*) to prevent the access of other such molecules.

I. Treatment of the Wounded Surface.—It will be convenient to consider, (1) the conditions which of necessity obtain in regard to the surface of a wound; (2) the modes in which carbolic acid has been applied to it, and to enquire whether, from the data we have obtained, carbolic acid is the best agent to employ as a primary dressing. A lacerated surface unites the following conditions which affect the operation of an antiseptic:—(*a*) putrescible material of an *albuminous* kind; (*b*) the presence of moisture; (*c*) exalted temperature, tending to volatilise any antiseptic capable of conversion into vapour; (*d*) an *absorbent surface* of living tissue, tending to remove from the wound-surface any agent capable of rapid absorption; (*e*) a condition of *sensitiveness of nerve structures*, rendering it advisable that any agent should be as little irritating as possible.

We turn to the *mode of application* of carbolic acid according to the antiseptic principles.

(1.) *The Application of Strong Carbolic Acid to the Wounded Surfaces.*—Mr. Lister's earliest cases were dressed with pieces of lint dipped in strong liquid carbolic acid; usually the primary caustic action produced much pain. The union of the carbolic acid with the serum of the exuding structures produces coagula, which form a tenacious mass over the surface. These coagula, like those of albumen before mentioned, themselves resist putrefaction, but the preservation of the surface beneath them is not so complete; the strong acid acts as an irritant, provoking a serous exudation which lifts the coagula, or the heat of the part can dissipate the protecting carbolic acid, and so suppuration can occur. Furthermore, it was found that the application of the undiluted acid gave rise to vomiting in the patients submitted to its influence.

(2.) *The Application of a Solution of Carbolic Acid in Oil.*—The oil chiefly used was boiled linseed, the acid being in the

proportion of one part to four: this was applied by strata of lint soaked in the dressing. Though this plan met with much success, it was observed that the lint absorbed the organic discharge, which it carried to its topmost layer, where, communicating with air, it could decompose, and the decomposing product could be carried back to the wound. Moreover, as I have shown,* oil impairs directly the antiseptic power of carbolic acid; thus, unless it is employed with the acid contained in large proportion, it is inefficient, and in this concentration it may be irritant.

(3.) *Saturated Aqueous Solution.*—This appeared to answer for the primary dressing of the wound equally well with the strong carbolic acid, and did not give rise to the serious inconveniences of the latter. Of all the forms to adopt for primary application of carbolic acid to a wound this appears the best, but it is open to the objections we have before noted,—that its contained carbolic acid is capable of rapid volatilisation and rapid absorption, with, of course, impairment of the antiseptic power of the solution; and the acid forming its definite compounds with albumen contributes to this impairment. Furthermore, an aqueous solution of this strength may yet be an irritant. There is a circumstance also to be borne in mind which may serve both as an objection and a caution—carbolic acid is not readily soluble in water. If it be attempted to make a solution rapidly with cold water, the result will be quite unsatisfactory. The liquefied acid agitated with the water will contain molecules of the pure acid irregularly distributed, but these will give no uniformity of antiseptic action,—there will be little or no true solution. If it is desired to make a strong solution rapidly, the pure liquefied acid must be shaken with two or three times its bulk of hot water, and then cold water afterwards added. But even when thus made a true aqueous solution, the application presents the disadvantage that it does not readily penetrate the effused products, so that the antiseptic may get into immediate contact with all the moist

* See pp. 17, 21, 121, 122.

albuminous tissues. Upon the moist tissues, as well as external to them, the same difficulties of solubility obtain, and consequently of even and perfect diffusion.

Having seen that certain theoretical disadvantages obtain in regard to the use of carbolic acid as a first dressing for wounds, we have next to enquire whether there are any other agents which present more probabilities of success. It would appear that that application would be the best which had the greatest antiseptic power upon an albuminous material in a moist state, that should be freely soluble so that it could thoroughly penetrate the exudation and the exposed tissues, and that should neither be too easily volatilised nor too rapidly absorbed. First we turn to the comparative energy of antiseptics upon albuminous compounds in the presence of water, and we find carbolic acid to be low on the list. The most efficacious are bichloride of mercury, chloride of zinc, sulphate of copper, perchloride and sulphate of iron. The late Mr. Nunneley, although with a total misconception of the scientific bases of the antiseptic method, made some valuable observations on the effect of various agents upon blood-compounds such as are met with on wound-surfaces. He said, "I have instituted numerous experiments by adding various substances to blood just drawn and still fluid, to coagulated blood, and to the serum alone; also, I have applied several of these, as pure alcohol, perchloride of iron, chloride of zinc, tannic acid, tincture of benzoin, sulphate of alumina, &c., to wounded and lacerated parts, for the purpose of ascertaining their effect, and the power which the resulting compound has of resisting decomposition and of being absorbed. Some of these, as the strong mineral acids, rather change and decompose the blood than simply coagulate it. Though the resulting compound, even when freely exposed to the air, will remain for many months unchanged, they are unsuited for employment; for if strong they destroy the tissues, and if weak are not effectual. Chloride of zinc forms with the blood a solid mass, which is not so dense or resisting as that formed by carbolic acid or perchloride of iron, and a greater proportion of the substance

is required to produce a corresponding effect. Alcohol forms a dense coagulum; tincture of benzoin answers still better, forming an odorous, solid, moderately unchangeable mass, and, I believe, deserves much of the credit so long attributed to the balsams; carbolic acid at once coagulates the blood, and forms a dense leathery mass, which decomposes very slowly; with the serum it forms a similar, but, as might be supposed, a less dense mass, from which fluid exudes. Perchloride of iron, of all these substances, appears to answer best. It acts promptly, a small quantity only is requisite, not more than one-sixth of the quantity of pure carbolic acid being required; it does not destroy or injure the bed-linen, as the acid does.* The compound is dense, adherent, very unchangeable, and, being composed of only those substances which normally enter into the composition of the animal body, is more adapted for innocuous absorption, if not for actual assimilation and incorporation with it. Alum forms a firm coagulum, and tannic acid answers admirably, forming a soft leathery mass, which is very unchangeable. Though the compound of blood and iron will remain without decomposition for months, a white mould forms in it much sooner than in the compound of blood and carbolic acid. It is also more soluble in water than is the latter. A small portion of a solid mass of three ounces of blood, with which two scruples of perchloride of iron had been mixed two months before, and exposed to the air with only a paper covering, was put into water, in which it became partially dissolved. A like portion of a compound of three ounces of blood, with two drachms of pure carbolic acid, was similarly placed in water, and after a month's exposure hardly any, if any, was dissolved. If solution be necessary for absorption, this experiment would lead us to infer that the iron compound is more readily absorbable than the carbolic acid compound." *

Thus we see that the metallic salts head the list in point of antiseptic efficacy, and they present the further advantage

* British Medical Journal, August 7, 1869, p. 155.

that they readily soak all the tissues and exudations, so as to render them all equally and efficiently non-putrescible. We should select from among them an agent which is as little irritant as possible, and which is not likely to be rapidly absorbed from the wound into the system, and thus its influence too soon removed.

Solutions of many metallic salts, nitrate of silver, sulphate of zinc, acetate of lead, sulphate and acetate of copper, bi-chloride of mercury, &c., have been used very commonly as dressings for wounds. It is needless to say that the experience of many who have thus employed them has shown that previously unhealthy wounds have assumed under their use more healthy characters; but there has not been a sufficiently defined method in their use to admit of a comparative estimate of their efficacy. Some agents, however, have been employed in a more systematic way, and data exist which may fairly indicate their value.

Chloride of Zinc.—A solution of this agent has long been advocated by Mr. Campbell De Morgan.* It is well known that when this is employed in a very concentrated form it acts as a powerful caustic: thus it may cause actual destruction of tissue and induce the suppuration which by its more moderate action it prevents. The strength of the aqueous solution recommended by Mr. De Morgan as a primary dressing for wounds is 40 grains to the ounce. The exposed tissues should be well soaked with it by washings and repeated spongings; the effect of this is that there is a sufficient imbibition of the solution by the living tissues and albuminoid exudations to render the antiseptic effect long persistent. At the moment of application there is usually a shudder indicative of pain (I have seen this manifest even under a tolerably deep chloroform-narcotism), but this is very transient. The washed surfaces of the wound assume a curdy-whiteness from the coagulation of the albuminous elements; the coagulum thus formed is incapable of decomposition. Under this treatment many cases of severe

* Brit. and For. Med. Chir. Rev., Jan., 1866.

wounds cited by Mr. De Morgan have been attended by rapid healing without suppuration. In cancer cases the application is superior to any other, because of its power of deep penetration into the tissues and of thus exercising its coagulating power upon the albuminoid constituents of cancerous matter, or, after extirpation of any cancerous growth, upon the cancer elements which may have escaped the knife. In the case of abscesses a once-for-all dressing after the evacuation of the pus has been attended with rapid healing with little if any suppuration, even in cases presenting the most unfavourable circumstances, as when connected with diseased joints in scrofulous subjects.* According to Mr. De Morgan's data, Professor Lister employed chloride of zinc with great advantage in compound fracture, in removal of the tongue, in extirpation of the maxilla, &c. Professor Lister, however, in general terms, declared his preference for carbolic acid, "except in one class of cases, those, viz., in which from the circumstances of the part concerned, it is impossible to maintain an efficient external antiseptic dressing, so that the application must be made once for all at the time of the operation." The reasons given by Professor Lister for his preference for carbolic acid are (1) its high antiseptic power; but this, under the circumstances existing in wounds, I have shown to be inferior to the metallic salts; (2) its volatility, which is an evil as well as a good, for it militates against its permanence, and its power of carbolising the air in its vicinity may be insufficient as well as irregular; (3) it is a local anæsthetic; but it at first, like chloride of zinc, causes a twinge of pain by its stimulating effect upon the exposed tissues of a wound. There is no doubt, however, that the chloride of zinc is the more painful application; (4) carbolic acid is, Professor Lister says, soluble in a variety of liquids of different properties. I cannot regard the behaviour of carbolic acid in this relation as of the advantage imputed to it. The variability of its compounds tends to the variability of its anti-

* Trans. Clin. Soc., 1868, p. 138.

septic action; and it is not so readily soluble and miscible with aqueous matters as is commonly supposed. There is scarcely a doubt that chloride of zinc as an antiseptic application to wounds has been attended with results of great value and importance; and Professor Lister, according to my personal knowledge, warmly testifies to the fact, especially under circumstances to which we shall presently revert. In the Middlesex Hospital, where antiseptic dressings have been used for some years, chloride of zinc being the chief, there has been a remarkable immunity from erysipelas.

We turn to another agent which has been recommended as a primary dressing to wounds.

Sulphurous Acid is of very high value as a soluble, permeable antiseptic of great efficiency under circumstances of moisture. Dr. James Dewar, of Kirkaldy, has strongly advocated it as a topical application to wounds and sores, and has adduced very successful cases in which it was thus employed. The wounded surfaces should either be sponged with the acid of full strength, or the spray of the fluid acid should be applied by a suitable vaporiser.* Cases of wounds in which, after dressing in this manner, there has been rapid healing with no discharge whatever, have been cited; but the dressings require frequent changing—at first once every six hours, according to Dr. Dewar.

Sulpho-carbolates of Zinc and Copper have been employed, especially by Mr. John Wood. The value of these agents, members of the series which I have had the satisfaction of introducing into therapeutics, consists in their being non-irritating and their action being gradual and prolonged. Mr. Wood has employed these salts, dissolved in water, in the proportion of 3 to 5 grains to the ounce; but I consider that they may be used with greater advantage in much higher proportions. The lotions may be applied by irrigation as well as by strips of lint, covered with oil-skin, as in water-dressing. Such a method "keeps the wound clean and free from smell, and has certainly much and beneficial

* Medical Times and Gazette, September 21, 1869, p. 318.

effect after operations upon tumours, &c., involving much subsequent discharge."*

It must not be supposed that the sulpho-carbolates are powerful *direct* antiseptics. They are inferior certainly to the two agents before discussed; their value, I consider, lies in the protraction of their action. The fluids slowly decompose the sulpho-carbolate, carbolic acid is liberated the while, as Mr. Wood has said, the metallic salt is exercising its own beneficial properties.

Chloride of Aluminium.—This agent has been more recently advocated by Mr. John Gamgee, and has been introduced into commerce under the name of chloralum. The error, however, must not be committed of regarding it as a novel antiseptic application. It has been long known, and many experiments have been made with it both in this country and in France. A reference to the table recorded by Dr. Angus Smith will show that this agent is far from occupying the highest place under those circumstances of albuminous material in a moist state which obtain in wounds. Mr. Gamgee has, however, shown that chloride of aluminium is very soluble and manageable, and it has the advantage of being free from all poisonous property; its power is very manifest in preventing the ill-odour of putrescent material. Moreover, its expense is small. It is a powerful astringent: this quality, though valuable in cases wherein hæmorrhage is to be dreaded, is not an unmixed good, for an agent which so strongly contracts the capillaries, is scarcely *primâ facie* likely to promote rapid union of lacerated parts. Mr. Lund, of Manchester, found that a solution of chloride of aluminium of a sp. gr. of 1·020 was irritating to the sound skin, unless the disengaged vapour had free exit. In a case of bruise of the arm, he used it according to antiseptic principles; but extensive sloughing took place, and it had to be discontinued.† The position of

* Mr. John Wood "On the Topical Treatment and Dressing of Wounds." Practitioner, Oct., 1869, p. 201.

† Brit. Med. Journal, Nov. 19, 1870, p. 567.

this salt as a surgical antiseptic must be considered as yet *sub judice*.

Emulsion of Tar (*Coaltar saponiné*).—As stated in a former part of this work, coal-tar has long been employed in France as an application to wounds. In 1859 M. Démeaux used a powder of plaster of Paris and tar; various other powders, of which tar was the chief constituent, took their rise from this, but many inconveniences attended them as a *primary* dressing to wounds. Their introduction into cavities or through any valvular openings of wounds was difficult and inconvenient, and in any irregular wounds the concretion of the solid plaster with the fluids of the parts rendered them sometimes irritant and always difficult of removal.

After many media for applying the coal-tar had been tried, such as alcohol, ether, acetic acid, and volatile oils, which were given up, either on account of the pain of their application or their costliness, M. Ferdinand Le Beuf recommended an emulsion of coal-tar made with saponine. M. Lemaire employed this emulsion in a large gangrenous wound with "extraordinary results," and afterwards confirmed his experience by other observations.* The saponine causes an extremely uniform diffusion of the slightly-soluble tar in the fluid and makes a stable emulsion; it can be used as injection, compress, irrigation, &c. In cases of burns, M. Lemaire found this emulsion of great advantage,† the proportion recommended being one part of oil of tar to 20 of water, with a sufficiency of saponine. In comminuted fractures it has been employed by many surgeons with excellent results, notably MM. Darricau and Petit, of Bayonne. The following case deserves translation, as touching on the question of priority of publication in regard to the antiseptic method in surgery. M. Lemaire says:—

"In November, 1862, a concierge of the Rue des Filles de Calvaire was taking down a notice-board which was placed above a high carriage-entrance—the highest in the street. He clung to the beam of the gate with his left

* De l'Acide Phénique, p. 12.

† *Loc. cit.*, p. 475.

hand; a hurricane blew at the moment, and the smaller gate, which was fixed in the greater, was banged to with violence. The ends of four fingers were crushed between the two beams; it was impossible for the man to extricate his hand from its horrid imprisonment. He managed to ring the bell; his wife drew the cord, and the gate opened; thus he was rescued, and saw the dreadful condition of his fingers, which poured forth blood. In order to make intelligible the pressure to which this poor fellow's fingers had been subjected, it is sufficient for me to say that the two posts of the new gate were so well joined that it was impossible for me to insert between them the blade of the scissors of my pocket-case. It would be understood that the soft parts and the bones must have been crushed, and, in fact, this was what took place. At the time of the accident, the nails of the four fingers were displaced, and only adhered to the matrix by a single point. The third phalanges were crushed, shreds of the skin hanging; the ruptured arteries and veins gave forth much blood. The first dressing was made by a chemist, who did all he could to re-unite the parts by little strips of linen; then he washed them with water, to which a little tincture of arnica had been added. I did not see the patient till the next day; he suffered horribly. The hæmorrhage was not completely arrested, the dressings were full of blood; I removed them all, and the hæmorrhage continued. I applied by the aid of linen strips a slight compression on these parts, and caused continuous irrigations of cold water to be practised. The suffering was extreme; the patient had not slept for 48 hours in spite of a strong opiate. At my second visit he said it was impossible for him to endure such suffering any longer. There was no longer any bleeding. I assured myself that the compresses were not too tight; then I dressed it with emulsion of coal-tar (1 to 15), and recommended that the dressings should be constantly moistened with cold water. A very sensible relief was obtained after the first dressing, and the second day the patient was so tranquillised that he slept for seven hours without awaking. He thought that

the coal-tar was a soothing dressing, for he had taken no narcotic. I did not remove the dressing till three days after the employment of the coal-tar. The tissues showed rose-red, there was neither swelling nor suppuration, cicatrisation was going on. The patient could move the fingers without suffering. The result appeared to me so remarkable that I sent for M. Géry, jun., who lived near at hand, that I might make him acquainted with it. Some days after, the nails had fallen off, and cicatrisation was complete. I saw the patient again a year afterwards; the nails were less regular than those which he had lost; sensibility was perfectly re-established, and the faculty of touch in the restored fingers as delicate as that of the fingers of the other hand. It was with difficulty one could recognise any traces of lesion. This observation seems to offer an important lesson in surgery. In crushed fractures, amputation is counselled. We have seen that in spite of cold water (recommended in such cases) for 48 hours the suffering gradually increased. It is nearly certain that if I had contented myself with this treatment suppuration would have been established and amputation rendered indispensable. Saponaceous emulsion of tar is employed; the pain is stayed at the first dressing, it disappears at the end of 48 hours, cicatrisation of the bones and soft parts takes place, everything is preserved. This good result obtained in respect of four bones, not only gives evidence of the remarkable properties of the coal-tar, but seems to me to indicate the employment of this method of treatment in cases of fractures (with crushing) of the limbs, before having recourse to amputation."*

This is sufficient to show how much credit is due to M. Lemaire as pioneer of the antiseptic system in surgery. In cases of recent wounds, M. Lemaire says that the coal-tar saponiné stops the formation of pus. If the wound is of older date it acts as detergent, and disinfects by killing the living ferments, speedily diminishing suppuration by

* Lemaire, *loc. cit.*, p. 563.

protecting the tissues and the products which they secrete from a renewed fermentation. Thus it favours their cicatrisation. Though carbolic acid produces like effects with those of the coal-tar saponiné, Lemaire prefers the latter, because the former is too rapidly volatilised by the heat of the parts; his preference is also shared by other observers.* I believe the coal-tar emulsion has been introduced into this country under the name of "liquor carbonis detergens."

We may now briefly review the position as regards the primary treatment of wounds according to antiseptic principles. If it were a question merely of applying the most efficient antiseptic in the organic conditions which obtain, one would conclude that the metallic salts (bichloride of mercury, chloride of zinc, or sulphate of copper) would be the most efficacious. But in respect of these we have other matters to consider; some may be too rapidly absorbed by the living tissues—this is likely to be the case with reference to the bichloride of mercury. We know, however, how good an application oxide of mercury in the form of black-wash is in some wounds; still the danger of the systemic absorption of the mercury militates against its use in large wounds. The next most potent appears to be chloride of zinc, and here practice seems to confirm theory. In some cases a single application of this agent has been sufficient to maintain a due antiseptic effect till cicatrisation has taken place. But the mere efficiency of an antiseptic as an antiseptic is not sufficient to establish its practical value in the composite conditions of wounds. Before attempting to determine the practical position of any special plan, we must consider the next desideratum which I have already cited, viz. :—

II. Prevention of Access of Putrefaction-Germs to Wounds Subsequently to the Primary Dressing.—It is obvious that one method of accomplishing this may be expressed in the two words—frequent dressings. Thus the antiseptic influence upon the effused products is restored, and any putrefaction-germs are destroyed. But the objec-

* *Loc. cit.*, p. 645.

tions are the irritation induced by repeated interference and the sacrifice of time and trouble which by other means can be spared. The old system of zinc-lotions differed only in its irregularity from this branch of the antiseptic method. There are various ways in which subsequent putrefaction may be prevented according to the antiseptic plan.

First plan : The primary antiseptic, as we have said, may so blend with the tissues as to render them incapable of putrefaction until such time as cicatrisation has been accomplished. This can, at least in certain cases, be done by *chloride of zinc*, and probably by some other metallic salts. It is certainly the simplest method of antiseptic treatment *en permanence*.

Second plan : The primary application may be such that its antiseptic principle is gradually given off, and thus its influence is protracted. This in all probability occurs in case of the solutions of *metallic sulphocarbolates*, on account of the gradually evolved carbolic acid, and the advantage of the soaking of the tissues with the metallic salt may be correlatively accomplished. A like result attends the tar-emulsion which is neither rapidly volatilised nor rapidly absorbed, and so long retains its antiseptic virtue. But in any case it is possible that the dressings may be allowed to become too dry; the effused products may wash away the applications, and the antiseptic influence may be annulled before a fresh supply of the application. Such danger is, of course, greater in valvular wounds, or where there are extensive cavities; then the only method to be adopted is, either total exclusion of air, or the rendering antiseptic any air which may possibly enter.

Third plan : After the primary dressing, exclusion of all air except such as is rendered antiseptic. Many means have been adopted for this purpose.

A. *Carbolised Oil.*—Pieces of lint or linen soaked in a solution of carbolic acid in 5 parts of olive, almond, linseed, or any of the fixed oils, may be applied over the wounded surface. This has been lately recommended as a ready method of treatment in military practice by Professor

Lister.* It renders necessary the previous application of a protective of prepared oiled silk (see Appendix). The material soaked in the carbolised oil should be in folds or layers, extending to the thickness of at least a quarter of an inch, and should reach a considerable distance, say 3 inches beyond the wound and the protective in all directions, the outer layer being somewhat larger than the rest, so that the margin of the mass of cloth may be thin. Gutta percha tissue sufficient to cover the whole should then be applied and retained by a roller steeped in carbolised oil.

As I have said before, though carbolised oil of a sufficient strength may give off sufficient carbolic acid to render air antiseptic, nevertheless oil is essentially a *bad* antiseptic vehicle. If nothing better be at hand this method should be adopted; but others offer more chances of success.

B. *Thin Sheets of Metal.*—Mr. Lister used at first sheets of tin, tin-foil having been found too porous. These were lined with putty made with carbolised oil. Carbolised oil is, however, a bad antiseptic, and it is irritant to the tissues. A better external casing, one that is more readily at hand, and the use of which has been attended with good results by several surgeons, is sheet lead, which may be moulded so as to exclude air very completely.

C. *Carbolised Plasters.* — The lead plaster and others impregnated with carbolic acid have given place to the lac plaster introduced by Professor Lister, which is certainly an elegant application.

When these are applied to a wound after the primary antiseptic dressing, care should be taken that they extend freely beyond the wound at every part, "so that the discharge may have to travel a considerable distance beneath the impermeable antiseptic layer before reaching the sources of mischief externally."† But the objection to the direct application of these plasters to a wound is, that the carbolic

* "A Method of Antiseptic Treatment applicable to Wounded Soldiers in the Present War," by JOSEPH LISTER, F.R.S., &c.; British Medical Journal, September 3, 1870, p. 243.

† LISTER'S pamphlet, On Compound Dislocation of the Ankle, p. 8.

acid which they contain itself acts as an irritant to the wounded surface. To obviate this, Professor Lister employs what he calls a protective. Here I think Professor Lister starts with a false premiss. He says that a substance employed to arrest putrefaction, "if sufficiently potent to destroy the life of putrefactive organisms, cannot fail to be abnormally stimulating to the exposed tissues; and these must be protected from its action if the wound is to progress exactly like a subcutaneous injury."* True of carbolic acid, this is quite incorrect in respect of other antiseptics. We have seen that the metallic salts will prevent putrefaction in far weaker solutions than carbolic acid—in such dilution that they cannot be irritant; and we have seen that wounds once treated with chloride of zinc will heal like subcutaneous wounds. Whilst, therefore, a protective (*i.e.* a non-irritant material capable of excluding any antiseptic which has an irritant action), is necessary when carbolic acid is liable to come in contact with raw surfaces, it is unnecessary when metallic antiseptics or tar emulsions are employed.

Mr. Lund, of Manchester, has recommended a material which he terms *antiseptic cere cloth*, as a substitute for the former plasters for covering wounds. It appears to be a very valuable suggestion, for the material is easily made, and is inexpensive. It consists of cloth or calico dipped in a mixture of paraffin, wax, oil, and carbolic acid, rendered fluid by heat.

"To illustrate," Mr. Lund says, "how effectually the vapour of carbolic acid, thrown off from this cere-cloth at ordinary temperatures will prevent putrefaction, I placed some pieces of fresh meat in several wire cages of a cubical form, covering each with the cere-cloth, and fixing it loosely round by an india-rubber band. This was done on the 12th of June last, and again on the 23rd of the same month; and, on opening one of the packets to-day, it will be seen that the piece of meat has remained unchanged, as far as putrefaction is concerned; although it has been

* *Loc. cit.*, p. 15.

kept in a warm room, it is quite dry and hard. To prove that this was due to the carbolic acid vapour and not to mere exclusion of air, on June 12th I also placed a piece of fresh meat in a cage, and covered it over in the same way with calico, steeped in exactly the same composition as far as the paraffin oil and wax were concerned, but *without* carbolic acid; and in less than nine days the meat was quite putrid and moist from decomposition, and I was compelled to throw it away." *

Professor Lister has more lately † recommended muslin or linen imbued with a mixture of paraffin, resin, and carbolic acid (see Appendix).

D. *Oakum.*—This has also been recommended by Professor Lister in the same communication. He prefers it to the lac plaster. Oakum fibre contains creasote and other antiseptic hydrocarbons which are insoluble in the exudations of the wound; hence its antiseptic effect is more permanent than that of carbolic applications. Under the lac plaster the skin is kept moist and becomes slightly irritated; under oakum, it is dry and is not irritated. It serves to drain away the discharge as fast as it exudes. Moreover, it allows the efficient strapping of wounds, which is impossible under lac plaster. "Under oakum an adhesive plaster retains its hold as well as under dry lint." Of course the plaster used should be rendered antiseptic (see Appendix).

E. *Carbolised Powders.*—It appears to me that this form of application for simplicity of employment as well as for fulfilling the chief ends of the antiseptic method, stands very high in value. Its disadvantages in valvular wounds, and those in which its perfect introduction is difficult, have already been pointed out; but these only apply to it when it is used as a primary and a sole dressing. It is a totally different thing when, the wound having been once treated efficiently with an antiseptic, this is used to prevent the

* British Medical Journal, September 4, 1869, p. 267.

† *Ibid.*, January 14, 1871, p. 21.

access of noxious air. It must be understood that whatever means be employed it is neither necessary nor possible to prevent the access of all air ; the exudations from a wound will sometimes defy all means intended to seal them up hermetically. All that is necessary is, that whatever air shall chance to enter shall be robbed of its putrefaction-inducing qualities ; and this is accomplished whenever it is sufficiently charged with carbolic acid. Application to a wounded surface (first rendered antiseptic by a fluid application) of a carbolised powder effectually antisepts the air by filtration through the grains of the powder. Many powders, harmless in themselves, are most valuable vehicles for carbolic acid. Among these are—

(1.) *Starch and various kinds of Meal.*—Carbolic acid can be incorporated with starch in any proportion up to 50 per cent; the higher percentages (those above 10 per cent) are somewhat moist: the mode of application is exceedingly simple: the powder is enclosed in a muslin or net bag, and dusted over the wound; this can often be done by the patient. I have had under my care large sloughing wounds of the neck following glandular suppuration from scarlatina heal with great rapidity when treated by this method. In severe *impetigo*, with great quantity of pus, two or three days of this treatment suffice to stop all suppuration. The proportions most useful to employ are from 5 to 10 per cent; of this percentage the powder does not readily pass through linen.

(2.) A still more valuable vehicle, which was first suggested to me by Mr. A. Davison, of Messrs. Balmer's, is *lycopodium:* incorporated with this, even to 50 per cent, carbolic acid readily passes through a muslin bag. It forms a soft and delicate powder excessively fine, and is very little disposed to cake. I have used it with great advantage instead of the starch powders.

(3). *Charcoal.*—Carbolised charcoal, especially animal charcoal, is extremely useful in cases of wounds which, at the commencement of treatment, are putrid and fœtid. It

combines the antiseptic with the deodorant, and enhances the action of each.

(4). *Plaster of Paris.*—Whenever it is desired to produce an antiseptic crust which shall exclude air as much as possible, carbolised gypsum, which is prepared with the utmost readiness, should be employed. It may be understood that these carbolised powders can in a very simple manner be a substitute for all the carbolised plasters which we have considered. If it be a small and superficial wound to be healed, after once rendering it antiseptic by a fluid according to data already given, the powder may be dusted directly upon the wound, and instructions given to the attendant that the powder be occasionally renewed, as the exudations make the surface moist. If it be an extensive wound, or the dressing after an operation, after full and complete washing with the liquid antiseptic, strips of linen soaked in the same can be applied, and then a coating of the powder, which, incorporating with the moist applications, makes a complete casing. Sufficiently frequent application of the powder causes all interstices to be filled up, and the end of thoroughly carbolising all the air which enters is attained. Of course, if it be preferred, the powders can be used as adjuvants to the plasters to obviate frequent changes. The powders are also specially applicable where, as in wounds of and operations upon the face, plasters on account of inequalities of the surface cannot be efficiently applied.

Repetition of Dressings.—Especially in regard to the antiseptic system is *nimia cura medici* to be deprecated. The dictum of Professor Lister cannot be too forcibly uttered, that for the healing of injured tissues no stimulant nor mysterious specific is necessary, but ALL THAT THEY NEED IS TO BE LET ALONE. There is a frequent impulse to look at a wound " just to see how it is going on," which is productive of no good and of much danger. I have heard of those who, by adopting all the preliminary measures, fancy they are adopting the antiseptic method, though they insist on inspecting the results of their handiwork without any efficient safeguard which the antiseptic system enjoins,

and condemn the method, the very conditions of which they do not fulfil. The repose necessary for recovery from wounds the antiseptic system absolutely enjoins. Nevertheless, there are circumstances in wounds which render repetition of the dressing absolutely necessary. Copious exudations may wash away the antiseptic first applied; dead portions of tissue may escape the influence; the antiseptic may be weakened by volatilisation or by absorption into the economy, or hæmorrhage may occur, and the wound must be explored. In the case of severe wounds, or in those inflicted for the performance of operations, it is generally necessary, from the amount of exudation, for the dressings to be entirely changed after the lapse of 24 hours. When this is done, great care is necessary to guard against the entrance of septic air, for Professor Lister says, "My experience leads me to believe that if, when the dressings are removed, a single drop of serum were to be pressed out by the movement of the limb, and then regurgitate into the interior after being exposed for a second to the influence of septic air, putrefaction would be pretty certain to occur."* In order to avoid this contingency, Professor Lister advises that a stream of carbolised water, 1 to 40, be injected by means of a syringe beneath the dressings previous to, and during, their removal, the irrigation to be kept up during the inspection of the wound. In subsequent experience, Professor Lister has used instead a spray of the solution, employed by means of Dr. B. W. Richardson's ingenious instrument for local anæsthesia. Obviously, any other antiseptic, as sulphurous acid or solution of chloride of zinc, can be employed in this way with, I think, greater prospect of success. Any materials or instruments introduced into the wound should, of course, be rendered antiseptic. I am quite convinced that when carbolic acid is employed as an antiseptic, it is advisable to avoid as much as possible a condition of moisture, and I think the application of the vapour of carbolic acid or air

* Compound Dislocation of the Ankle, p. 14.

blown over the hot liquid acid would be of most value as an antiseptic atmosphere to permit the inspection of a wound. The solutions of the metallic salts are, however, good antiseptics in presence of moisture, and may be employed for the examination as irrigations or as spray; their antiseptic effects are, moreover, much more permanent, so any hurry in re-dressing may be avoided by their use. As exudation tends to cease and cicatrisation begins, the intervals of dressing are to be prolonged, only the external means, whatever it be, of rendering the chance air which gets to the wound antiseptic must be put in force. The intervals of dressing in the severe case of compound dislocation of the ankle treated by Professor Lister were these—1 day; 1 day; 2 days; 3 days; 5 days; 5 days; 7 days; 8 days. In military practice, respecting the oily application before discussed, Professor Lister says, "The times of changing the outer cloth or treating it with fresh oil should be in accordance with the amount of discharge. During the first 24 hours the effusion of blood and serum is necessarily profuse, and it will be well that fresh oil be applied to the outer cloth within 12 hours of the first dressing, or even in 6 hours if there should be unusual oozing. On the second day, also, in the case of a large wound, two dressings in the 24 hours will be desirable. After this, if all go well, the discharge will diminish quickly, and a daily renewal of the antiseptic supply will be sufficient; and when 5 or 6 days have passed to apply the oil once in 2 days will be all that will be required. This, however, should be continued after discharge has ceased entirely, till sufficient time has passed to insure that the wound has healed by scabbing, or at least has been converted into a superficial sore."* In the latest case recorded—forcible compound re-fracture of ulna and radius for faulty union—the following were the intervals of dressings:—1 day; 2 day; 4 days; 4 day; 5 days.

Practical Summary of Antiseptic Treatment of Wounds.—(A.) The wound is simple and superficial.

* Brit. Med. Journal, Sept. 3, 1870, p. 244.

Wash it with solution of chloride of zinc (40 grs. to oz.), of carbolic acid (5 per cent), or any of the liquid antiseptics mentioned. Apply material to constantly render the air which may get to the wound antiseptic. Carbolised materials best accomplish this; apply (*a*) carbolised powder, or (*b*) carbolised plaster, or (*c*) oakum.

(B.) The wound is extensive and presents a cavity.

Thoroughly antisept by irrigation and sponging with (*a*) solutions of metallic salts: as chloride of zinc, or (*b*) sulphurous acid, or (*c*) coal-tar emulsion, or (*d*) aqueous solution of carbolic acid (5 per cent).

Secure all vessels with ligatures rendered antiseptic by soaking; if of silk or such like absorbent material, in antiseptic solutions; if of cat-gut, by the preparation indicated. (see Appendix.)

Bring edges of wound together by metallic or antiseptic stitches, or by antiseptic plaster.

Exclude from wound all air, except such as is rendered antiseptic by applying (*a*) strips of lint soaked in antiseptic solution, and afterwards well coated with carbolised powder, or (*b*) metallic plates, as lead-foil, or (*c*) carbolised plaster, or (*d*) oakum.

In renewing dressings never expose a wound unless you are sure you can irrigate it in every part with an antiseptic solution.

If this be doubtful, remove the dressings under antiseptic vapour, spray, or stream, and keep it up until fresh antiseptic dressings are applied.

CHAPTER XXV.

EMPLOYMENT OF CARBOLIC ACID IN THE TREATMENT OF SURGICAL AFFECTIONS.

Boils and Carbuncles.—M. Lemaire relates, in his work,* three severe cases of *anthrax* in which carbolic acid was applied, with rapid amendment of both local and general signs, and with ultimate cure. In these cases the dead tissues were, as far as possible, removed, and the saturated aqueous solution of carbolic acid was applied so as thoroughly to impregnate the exposed parts; then a compress soaked in the carbolic lotion (½, 1, or 5 per cent) was kept over the surface. In one case, through an opening made by the sloughing of the skin, the saturated aqueous solution was injected into the cavity. In all cases a great relief of pain followed even the first dressings. Dr. Cleborn, U. S. A., in whitlows, boils, and abscesses, adopted the following method:—He made a free opening as soon as fluctuation was detected, and, when the pus was gently expressed, injected liquid carbolic acid, after which cold water dressing was applied. Thus suppuration was prevented, and the wound healed rapidly; the patients were enabled to return to duty in two or three days, and in some cases—the edges of the wound being brought together by isinglass plaster—complete healing took place in twenty-four hours.† Dr. Peter Eade, after free incision of an extensive carbuncle at the back of the neck, and subsequent poulticing, dressed the wound with lint soaked in carbolised oil (1 to 5). In two days great improvement was manifest. "Pale, flabby, and sloughy cellular tissue became quickly covered with new red, and even florid, granulations; the amount of suppuration was much diminished, and throughout a much smaller quantity than usual of shreds of slough were discharged; whilst the diseased skin, when its spread was once arrested,

* De l'Acide Phénique, p. 452.

† Amer. Journ. of Med. Science and New York Med. Record, quoted in Brit. Med. Journal, Feb. 20, 1869, p. 164.

appeared to regain with great rapidity its natural level, colour, and consistency."* Mr. Purves records a case in which he employed carbolised glycerine after the core of the anthrax had completely formed, with the effect of causing a rapid contraction of the large and gaping wound.†

Our further knowledge of the properties of carbolic acid leads to an improvement, I think, upon all these methods of procedure. I have myself treated several cases of boils, carbuncles, whitlows, and abscesses, upon the following plan :—The patient presenting himself in the stage of local inflammation with much suffering previous to the softening of the core, the whole surface of the inflamed part is brushed over with strong liquid carbolic acid, or with a mixture of it with an equal part of acetic acid. The acute sensitiveness of surface is at once subdued. Cold, tepid, or warm dressings are then kept applied. The patient is furnished with a small quantity of the strong carbolic application, and instructed to repeat the painting of the surface once or twice daily. When he presents himself a few days afterwards, the skin superincumbent on the diseased cellular tissue has been rendered by the carbolic acid completely anæsthetic. The pus is painlessly evacuated, and the wound is treated according to the principles already laid down. Especially in the after treatment, I have found the carbolised lycopodium powder valuable.

Gonorrhœa.—Weak solutions have been used as injections in this affection (1 per cent and weaker) with advantage in some cases, but there has been far from uniform success. Injections of emulsion of tar (1 to 10) seem to have been of greater advantage.‡ In the case of the delicate membrane of the urethra it is difficult so to graduate the strength of the lotion employed as to obtain efficient suppression of exudation without at the same time its own effect of irritation being too highly manifest. I do not think the carbolic lotion possesses any advantage over the metallic salts. A

* Lancet, December 11, 1869, p. 800.
† *Ibid.*, January 29, 1870, p. 180.
‡ De l'Acide Phénique, p. 465.

solution of sulpho-carbolate of copper or zinc has been used with advantage, and with no irritant effect whatever.

I have employed weak carbolic lotion in cases of *balanitis*, such as frequently occur in female children, with much advantage. The plan usually adopted has been to prescribe a strong (5 per cent) lotion, with instructions that at the commencement of treatment injections be administered, consisting of one part of the lotion to five parts of water; if necessary, the strength can be progressively increased.

Cancer.—Lemaire records four observations which cannot fail to draw attention to the remarkable effects of carbolised dressings upon cancerous ulcerations. Besides a great improvement in the wound—cleansing, removal of odour, arrest of exudation—an effect was manifest upon the cancerous elements themselves. In several cases the ulcerations cicatrised; *pari passu*, the general cachexia passed away, and the patients returned to almost normal health. MM. Bazin, Drumen, and Petit also obtained very good results.

In the first case recorded by Lemaire, an extensive cancer of the left breast, ulcerating and suppurating, with a copious fœtid discharge, requiring the application of fourteen or fifteen napkins each day, was treated by lotions and compresses of the emulsion of coal-tar (1 to 10). Immediate disinfection took place, pain was subdued, and in ten days secretion was arrested. As treatment progressed the health improved, appetite returned, digestion became better, there was natural sleep. More than a year afterwards the patient was observed in apparently perfect health; the skin was sound, but beneath it there had been increase of the cancerous tumour, which was about one-third larger than at first. The tar application was preferred to the dilute carbolic acid.

The second case recorded was cancer of the vulva, vagina, and perinæum, in which gangrene had invaded the labia, nymphæ, and vagina. The patient was in a most alarming condition. The coal-tar emulsion was applied, and a sponge impregnated with it was placed in the vagina. Lemaire recommends the simple plan of first placing the sponge

in situ (which can be done by the patient herself), and then impregnating it with the lotion by means of an injection. Gangrene was at once arrested, and complete deodorisation occurred ; healing took place to a large extent, though passages had been established between vagina, bladder, and rectum. After eighteen months, the dressings having been incompletely made, sloughing recurred, but was promptly checked by the tar application. Meanwhile the patient recovered health and strength, and was able to take walking exercise. This patient also found a greater benefit from coal-tar emulsion than from a solution of the pure carbolic acid.

In a third case, one of ulcerating cancer of the breast, weak carbolic lotions and compresses steeped therewith were employed. The disease was making rapid progress, but after the treatment ulceration was entirely checked ; ultimately pulmonary symptoms supervened, which caused death. " M. Cruveilhier," says M. Lemaire, " etait étonné de l'étât de fraicheur qu'avait conservé l'enveloppe cutanée après quatre années de l'existence du cancer."

The fourth was a frightful case of cancer of the face, from the upper lip to the forehead. The odour exhaling from the diseased mass was so insupportable that the people of the neighbourhood complained to the commissary of police, and demanded the removal of the sufferer. In this case saturated solution of carbolic acid was applied, and, to disinfect the nasal passages, the strong alcoholic solution was so placed that the vapour should be inspired. Great improvement took place ; fœtid odour disappeared, and the appetite of the patient returned. Further details of the case are wanting.

In a case of *epithelioma* above the right eye-lid, which resisted other methods of treatment, weak carbolic acid lotion (1 to 1000) was applied; after twelve days of the treatment cicatrisation was complete. Four years after it continued completely healed. There are records of several other similar cases.

Dr. J. R. Wolfe has recommended and illustrated a combination of methods for the treatment of cancer, which

seems of the greatest practical utility. The plan consists of the destruction of the tumour with caustic arrows, and the treatment of the wound by carbolic acid. In a case of epithelioma of the inner canthus, of nine years' standing, involving both eye-lids, five openings were made in the tumour, and caustic arrows inserted. On the third day the tumour sloughed away; the wound was now painted with strong carbolic acid, and covered by wadding dipped in glycerine. In three days there was a uniform granulating surface. It was then covered by carbolised wadding dipped in glycerine, the dressing being changed every second day, and the wound washed with weak solution of carbolic acid. The "caustic arrows" are made by mixing chloride of zinc into a stiff paste with starch, rolling into shape, and drying.*

I have had an opportunity of personally observing the apparently extraordinary power of carbolic acid to induce the formation of a perfect cuticle over a cancerous mass. A lady, aged 40, who had been my patient several years previously, called my attention on October 5th, 1867, to two painless nodules, of the size of filberts, situate in the left breast. From the peculiar dyscrasia, though not from the appearance of the nodules themselves, I gave my opinion that they were cancerous, and advised, subject to the approval of an eminent surgeon, extirpation. My diagnosis was, however, not confirmed; they were considered fibrous, and a twelvemonth was devoted to general tonic treatment, including a prolonged stay in a healthy part of the North of Scotland. On presenting herself early in October, 1868, I found a single hard tumour, the size of a large lemon, measuring 4 inches in its long and 3 inches in its short diameter. A gland of the axilla, also, was indurated. Sir Wm. Fergusson, on October 21st, extirpated the cancerous mass. Soon after the operation fungous cancer appeared in the wound, which presented a large ulcerating surface. Under treatment, first by carbolic oil, afterwards by carbo-

* British Medical Journal, August 8, 1868, pp. 150 and 303.

lised starch powder, granulation occurred, and rapid healing took place. Nothing could more directly show the advantage of the carbolised powder; the wound was kept constantly dry and sweet; the application was made with no trouble, even by the patient herself, the muslin bag containing the powder being kept always at hand. The skin healed so as completely to cover the surface, with not a spot whence exudation proceeded. Thus the distress of the open wound, with its discharge and fœtor, was entirely done away. The patient recovered so as to be able to be removed for change of air. On March 4th, 1870, a strange and lamentable accident occurred: the patient was merely walking across her bed-room, when, by the mere pressure of the foot upon the ground, the thigh-bone (which was thus proved to be cancerous) broke. Then followed a period of grave distress; bed-sores formed, which, however, entirely healed when treated with poultices made with water to which Condy's fluid had been added. The patient had many peaceful days afterwards; no open sore whatever re-appeared. She died November 26th, 1870, more than two years after the operation.

External Syphilis.—Lemaire treated many cases of chancres and chancroid ulcerations with emulsion of coal-tar and with carbolic acid. The results were doubtful; in some cicatrisation took place rapidly; in others, though there were appearances of stimulation, healing was slow. In phagedænic chancres, however, the benefit was very manifest. Ricord, than whom there can scarcely be a greater authority, says, "I have employed carbolic acid diluted in various proportions, according to the indications of Dr. Lemaire, for several patients in the Maison de Santé de la Rue de Lorraine, for ill-conditioned wounds which had been very refractory under ordinary methods: for example, perforating phagedænic chancres, which have a great tendency to persist; for secondary ulcerations, presenting also a phagedænic taint, with abundant suppuration and discharge. The solutions of carbolic acid have favourably influenced these wounds, reducing, in an evident manner, the extent of

the suppuration, and modifying rapidly the ill aspect of the ulcerated surfaces, which were cleansed, and which assumed a better colour. A pronounced disinfecting action must be added to these results."*

Mr. Holmes Coote has employed carbolic acid applications in the treatment of the primary forms of syphilis. In one case of mucous tubercles of labia and thighs, an aqueous solution of 5 grains to the ounce was employed—cure took place in three weeks. In a second case, of greater severity, besides the use of the lotion, an application of equal parts of the strong acid and water was painted over the surfaces each day—the case was well in twelve days. In a third case, similar to the last, the period of treatment was fourteen days. Mr. Coote says the plan has been followed with success on several foreign stations. Soft chancres were also treated by carbolic acid with good results. Healing took place usually in ten to fourteen days.†

Mr. Sealy Smith, of Seaforth, Liverpool, has recorded a very successful case, in which carbolic acid was used in syphilis accompanied by severe throat symptoms. The disease involved a great extent of the throat; the tonsils and uvula were destroyed, and the whole of the pharynx, as far as could be seen, was a sloughing surface ; much of the muscular substance of the pharynx had sloughed, and the disease extended into the nasal passages, from which there was a constant discharge. Swallowing was scarcely possible, emaciation was extreme, and circulation very feeble—in fact, the patient had given up all hope of life. Liquefied carbolic acid was brushed over the whole diseased surface, and afterwards the patient took much liquid food, and iodide of potassium (10 grains) with Battley's solution of opium and cinchona internally. A weaker solution (1 to 60) was now used twice daily. Much amendment took place, and the patient was enabled readily to take food. After fifteen days, carbolised glycerine (1 to 30) was employed, the inter-

* Lemaire, De l'Acide Phénique, p. 498.

† Brit. Med. Journal, March 14, 1868, p. 241, and April 25, 1868, p. 414.

vals of its application being subsequently increased. The patient obtained a new lease of life; the throat filled up to nearly its usual size, and nothing remained but a nasal gleet. "The excessive soreness began to decrease after the first application. The secretion from the diseased surface, which was mopped away each time as much as possible, also regularly decreased in quantity, and became less offensive. After the first few days a new action was evidently set up, healthy granulations made their appearance, and the whole aperture of the throat, both above and below, was reduced in size."*

Gangrene.—Lemaire, in 1859, published a series of cases in which excellent results attended the use of coal-tar emulsion in moist gangrene. Dry gangrene, which Pasteur has confounded therewith, is, of course, a mere desiccation of tissue from arrest of nutrition, and does not present the same indications for the employment of an antiseptic. Carbolic acid, Lemaire says, is a crucial remedy for moist gangrene. "It arrests its invasion, disinfects all the mortified parts by killing the living germs with which they are filled, dries up pus products, favours the falling of sloughs; in fact, by destroying the germs which the atmospheric air deposits constantly on the wound, it protects the healthy tissues from the injurious action of these germs, and prevents renewed decomposition; thus it favours cicatrisation."† Many observers, continental and English, have attested the value of carbolic acid in gangrene.‡

Purulent Ophthalmia.—Carbolic acid diluted with water has been employed by M. Foucher, and by M. Coursserand, as lotion and irrigation in this affection. M. Sénéchal used copious injections of a 2 per cent aqueous solution: in two cases of infants cure resulted in four days.§

Ulcers.—Lemaire used coal-tar emulsion, with the result of great amendment or rapid cure, in a large number of

* Lancet, June 4, 1870, p. 802.

† Lemaire, *loc. cit.*, p. 580.

‡ See a case by Mr. H. Dodd, Brit. Med. Journal, March 5, 1870, p. 231.

|| Lemaire, *loc. cit.*, p. 603.

callous, cancerous, scrofulous, syphilitic, and gangrenous ulcers. He now recommends a 1 per cent aqueous solution of carbolic acid as a wash and a dressing. Maissonneuve considers carbolic acid as the most powerful known disinfectant of wounds. He has been confirmed by many English observers.*

CHAPTER XXVI.

ABSORPTION OF CARBOLIC ACID FROM THE SURFACE.

There are many facts which show that the absorption of carbolic acid from the surface, whether of a wound or of the unbroken skin, is very rapid and energetic.

This has been observed in *animals*. A dog affected with scabies was enveloped in a bandage which had been soaked in a mixture of one part of carbolic acid in two parts of glycerine. In a few minutes the animal fell back, became convulsed and unconscious, and nearly died. Repeated washings with soap and water and cold douches were practised, and after a few hours recovery commenced.† In many other instances there has been a fatal result. Dr. Wallace mentions an instance in which for destroying fleas in a dog a chemist had advised a "carbolic acid bath" (strength not stated). The dog died in ten minutes.‡ Dr. Muter caused a solution of carbolic acid to be used to a cat for a similar purpose. A few minutes after the first application the animal became convulsed and ultimately died.|| Certain birds, however, seem most susceptible of the toxic action of carbolic acid externally applied. M. Lemaire applied two drops only of pure carbolic acid to the præcordial

* Lemaire, *loc. cit.*, p. 686.

† *Ibid.*, p. 69.

‡ Brit. Med. Journal, April 30, 1870, p. 432.

|| *Ibid.*, p. 561.

region of a sparrow; two minutes afterwards it became unsteady and would have fallen, but that its tail acted as a prop; soon after the limbs became agitated and there seemed to be much suffering; the symptoms abated by degrees, and three hours afterwards recovery was complete. In another sparrow, however, when three or four drops were used, death took place in half-an-hour.

In the *human subject* also, there is abundant evidence of toxic action from the absorption of carbolic acid from the surface. Lemaire observed in three patients affected with *lepra* that, immediately after the application by means of a bandage of a 6 per cent acetic solution of carbolic acid, phenomena of vertigo were manifested. These occurred at each dressing, the patients being under observation for three months. They were each time obliged to lie down, but they recovered completely in half-an-hour.

In cases in which carbolic acid has been employed for surgical dressings there have been manifest toxhœmic effects. Among these one of the most prominent has been *vomiting*. The experience of University College showed this to be a common result of the carbolic acid treatment of wounds; but it should be recollected that this was chiefly at a time when the agent was employed pure or in strong proportions. There is sufficient evidence to directly connect the vomiting with the carbolic application. Another evidence of its systemic absorption was a *peculiar effect upon the urine*. This, I believe, was first noticed by Mr. Berkeley Hill. Occasionally the urine of a patient whose wounds were dressed with carbolic applications was found to be highly coloured, as if he were suffering from hæmaturia.

A case, interesting and significant, is recorded by Dr. Lightfoot, of Wincanton.* In a lady of fifty-one, after excision of the elbow, the wound was dressed with weak carbolic lotion (2 per cent). At the end of 72 hours, rigors, pyrexia, and uncontrollable vomiting occurred, symptoms all suggestive of pyæmia. On the 5th day after the operation the condition was alarming, the vomiting

* British Medical Journal, April 2, 1870, p. 331.

being ceaseless. The carbolic dressings were now changed for linseed poultices, when all the symptoms abated. A week afterwards the carbolic applications were resumed, whereupon the vomiting and all the evil symptoms recurred. On leaving off the dressings they ceased. A third time the weak lotion was injected into two sinuses which remained; slight sickness after food followed and led to their being discontinued, when all the mischief subsided. There could be no doubt as to the cause of the symptoms; and the case proves that in some persons exceedingly small quantities absorbed from the surface will produce toxic effects. In the case thus recorded there was no characteristic effect upon the urine; but in many other cases in which carbolic acid has been used as an external dressing, such has been noted. Dr. Wilks, in a note inserted in Dr. Lightfoot's communication, mentions a case of typhoid fever, in which extensive bed-sores existed, and says, "For two days I dressed them with lint soaked in carbolic acid (one part to five of linseed oil). After the second dressing severe and continuous vomiting occurred, and the urine became very dark (as with anasarca after scarlatina), leading me at first to think that there was hæmorrhage from the kidney. On discontinuing the carbolic dressing the vomiting ceased, and the urine became natural. Under the microscope there were no signs of blood-corpuscles, only dark amorphous particles as of carbon." Dr. James Wallace, of Liverpool, also gives an interesting record* of the case of a strumous child, in whom an abscess connected with the hip joint was dressed with 1 part of carbolic acid to 8 of olive oil. After each dressing symptoms of vomiting occurred, and the child became sallow, cachectic and extremely prostrate. The urine was of a smoky tinge, of a specific gravity of 1010 to 1015, but contained not a trace of albumen. An excess of nitric acid being added to the boiling urine a dark precipitate was thrown down, which on some occasions only gave evidence of the presence of bile-acids. Under the microscope this precipitate

* British Medical Journal, April 30, 1870, p. 432.

appeared as "yellow, brown, ruby red, and black pigments." Dr. Wallace concluded that the carbolic acid was carrying off the pigment of the blood corpuscles. The exact nature of the change effected upon the urine requires, however, more careful investigation. Dr. Stevenson, of Guy's Hospital, showed that urine darkened by the systemic absorption of carbolic acid did not contain more than the normal quantity of iron; he considered that the colouring matter was not derived from the blood. The more probable hypothesis is, that it comes from the changed carbolic acid itself. However this may be, and we shall subsequently return to the question, the peculiar condition of the urine, as well as the other toxic effects mentioned, are the direct results of the absorption of carbolic acid; there is no doubt that the condition of darkened urine, however, may occur without further manifestation of danger or discomfort.

But, moreover, the cutaneous absorption of carbolic acid has occurred in several instances in the human subject even to a *fatal extent*. Mr. Machin, of Erdington, Birmingham, records the following case.* In the Aston Union Workhouse three women, aged respectively 68, 60, and 23, were dressed with Calvert's crude carbolic acid in mistake for sulphur lotion. The acid after having been warmed had been applied to the entire surface of the bodies by means of a sponge. Within a few moments smarting pain and headache occurred, and then giddiness and unconsciousness, with spasmodic breathing. The patient aged 60 never rallied; the breathing became slower and more laboured, the pupils were natural and responded to light; death took place about four hours after the application. The youngest patient, after an insensibility of five hours, gradually became conscious, and much retching occurred. A very strong odour of carbolic acid was perceived with each expiration; the respiration lost its spasmodic character, but became quick and irregular. Pain in the head and throat occurred, and after some time an epileptiform convulsion

* British Medical Journal, 1868, p. 220.

came on.* Lastly, symptoms of congestion of the lungs became manifest, and the patient, conscious to the last, sank gradually, and died 40 hours after the application of the acid. The eldest patient (aged 68) rallied from her unconsciousness after four hours. She described her first symptoms as those of intoxication with constriction of the head. After rallying there were no particular symptoms, the skin was thrown off in small scaly patches; complete recovery took place. Another case in which a child of 12 months old died from the effects of carbolic acid applied to the surface is recorded by Mr. Edward Sandwell. The circumstances were singular; they are appended in Mr. Sandwell's own words :—

"On August 31st, Emma ——, aged 12 months, came under my care suffering from extensive ulceration of the whole of the gluteal region, together with the labia, &c. The mother of the infant is charwoman to the Ragged Schools in this district; and, having on the 29th of August to clean the rooms, took with her the baby and another child 12 years of age to look after her. Just before she commenced working, the superintendent had used his usual disinfectant of one ounce of carbolic acid to a quart of warm water, which he sprinkled about the room, as was his practice. The elder child sat the baby on a block of wood on which some of the disinfectant had been thrown. Nothing was noticed on the day of the occurrence, the child being washed and put to bed as usual. The next morning, blistering had commenced, and rapidly passed into the state of ulceration in which I first saw it. I ordered a dry application of Fuller's earth and French chalk, which seemed to comfort and cause a diminution of the inflammation. On the fifth day after the accident, I gave a lotion of liquor plumbi with glycerine. Several sloughs formed and separated, the child gradually becoming weaker from exhaustion and shock. There were some signs of internal

* The girl had been previously epileptic.

inflammation, for which I applied the usual remedies. The child died on the tenth day.

On making a *post mortem* examination, I found the rectum much inflamed; the intestines had patches of inflammation; the right pleura was also much inflamed.

Before the accident, the child was very healthy, showing no signs of internal inflammation or other disease. It was well forward with dentition, and was a full, robust child; but after the injury, emaciation was very rapid.

From inquiries, I find that it is not at all uncommon for people to complain of burning and even blistering of the gluteal region after having used a closet to which carbolic acid had been recently applied. This only tends to show the necessity of caution being used in the administration of this disinfectant, even in a diluted form."*

The only comment I am inclined to make in addition to this narrative is, that it appears to me very probable that the injuries were really inflicted, not by a dilution of carbolic acid, but by the strong agent itself; for there is no doubt that by the mere admixture of the ounce of carbolic acid with the quart of warm water no true solution was made, the acid was merely distributed, and it was this which produced such violent local irritant effects. The internal inflammation was the effect of the absorbed poison.

Another case of death is recorded from the administration of a solution of carbolic acid by mistake as an *enema*. Even whilst the nurse was applying it, the patient suddenly fell in a fit and became stertorous; he died in about twenty minutes.†

The foregoing data are sufficient to point many useful lessons and cautions. There has been too great a tendency to regard carbolic acid as an innocuous agent, whereas it requires great care in its employment. Scarcely anything more strongly demonstrates the function of the skin as an absorbent; it appears that to whatever portion of the

* British Medical Journal, October 8, 1870, p. 382.

† Pharmaceutical Journal, May, 1869, p. 656.

surface of the body applied, whether external or internal, the agent is absorbed with almost equal rapidity. Great caution should, therefore, be used when large cuticular surfaces are subjected to the influence of carbolic acid. Thus, if a solution containing it be used as a remedy in itch, directions should be given that portions only of the surface should be acted upon at a time. It has been recommended that after recovery from some of the zymotic diseases, the whole surface of the body should be washed or anointed with a carbolised application. Here, also, great caution must be used; the effects in the debility after acute illness might be severe even in small proportions, and it must be recollected that certain people manifest a strange susceptibility to the effects. The carbolic acid soap, introduced by Mr. Calvert, seems quite destitute of danger, although it contains a large proportion of the acid; but there are other antiseptic agents which may more than vie with it in efficacy as an application in such cases, for its rapidity of absorption of course impairs its persistency of action. We have shown that camphor is a potent antiseptic; this, in the form of camphorated oil, I have frequently recommended for external application to prevent infection—it seems very efficient, and is certainly harmless. The circumstances also confirm the opinion I have stated, that carbolic acid is *not* the best primary application to recent wounds. The rapidity with which it is removed from the wound surface by absorption, and hence the impairment of its antiseptic action, as well as the toxic effects which this absorption is capable of inducing, place this agent far behind others which, though equally potent antiseptically, are less dangerous. On the other hand, I am sure that nothing so efficiently renders antiseptic the air, and hence nothing is so valuable as an external application for ridding the air which may come in relation with a wound of its dangerous qualities. Again, I think the use of carbolic acid in any form as an enema should be discouraged. M. Lemaire, nevertherless, advised it to be thus used for the treatment of ascarides. In a child of eight, he employed 21 centigrammes of the

pure acid dissolved in 125 grammes of water; in two others the proportion was 50 centigrammes in the same quantity. Two enemas each were sufficient, it is said, in each case for complete cure. M. Gratiolet also thus employed carbolic acid with success.* Dr. Kempster, in the "Richmond and Louisville Medical Journal," also recommends it as a remedial agent in this form. He says the *Oxyuris vermicularis* can be at once destroyed by using as an injection a drachm of a solution of carbolic acid (of 2 grains to the ounce) to 4 ounces of water. The proportion thus employed is extremely small, and would scarcely produce toxic effects; but looking at the danger which might occur from the chance employment of too large a dose, I do not think the treatment is to be preferred to that by the harmless injections, with the value of which in the treatment of thread-worms, we are well acquainted—such are solutions of the sulphites, of common salt, or infusion of quassia, &c. Again, a lesson of caution is inculcated in the distribution of carbolic acid as a disinfectant, especially where children are likely to come in relation with it. At all times where it is used with a fluid medium, a *definite solution* of it should be made, and care should be taken that any surface while yet moist with it shall not come in direct contact with the skin.

CHAPTER XXVII.

CARBOLIC ACID IN INHALATIONS.

Carbolic acid is so volatile that its vapour can be readily administered. To all low forms of living things it is, as we have seen, rapidly and energetically fatal; even large insects are killed by it. It appears, however, that its vapour

* LEMAIRE, De l'Acide Phénique, p. 462.

is not poisonous to any animal of warm blood. Lemaire found that mice were unaffected by an atmosphere impregnated with carbolic acid. He caused also a horse to breathe air impregnated with carbolic acid by passing over tow moistened with the agent and contained in the nose-bag applied to the animal. Though this was continued for an hour and a half, and evaporation was accelerated by the heat of the sun, there was no sign of toxic influence whatever.* Crookes also found that the vapour of carbolic acid was never injurious nor unpleasant to cattle.† There is evidence, also, that persons habitually accustomed to inhale carbolic acid experience no ill effects, but, on the contrary, are usually in exceptionally good health. When the vapour given off from carbolic acid at the normal temperature of the air is breathed, a little dryness of the throat is usually experienced, and bronchial exudations are diminished, but there no other signs of discomfort. M. Lemaire employed inhalations of the agent for the treatment of various diseases of the respiratory passages. His method was this—he placed about 20 drops of the acid, liquefied by alcohol, at the bottom of a deep flask, and caused the patient to inspire the vapour from the mouth of the flask three times a day, for from 3 to 5 minutes; inspiration was practised through the nostrils, of course, if it was necessary to act upon the nasal passages. Lemaire stated that this method was far preferable to the inhalation of the vapour proceeding from boiling water to which carbolic acid had been added. Occasionally ether instead of alcohol was used with the acid, but it was thought that in this case volatilisation was too rapid.‡ Lemaire tried the inhalation in cases of hæmoptysis, but found that it had very little direct action in restraining the hæmorrhage; it might act indirectly by restraining cough. In phthisis, however, he considered that it had a very beneficial action. It must be remembered that this treatment was combined with the internal administration

* Lemaire, De l'Acide Phénique, p. 73.

† Report to the Cattle Plague Commissioners, Reprint, p. 32.

‡ *Loc. cit.*, p. 402.

of carbolic acid. Lemaire says:—"Inhalations of the vapour of this acid mingled with air, and its internal employment in aqueous solution have produced very remarkable effects, which I am about to describe. The cough diminished considerably in the majority of cases after 48 hours. In some it disappeared almost completely in a few days. Expectoration decreased in all cases; in some it was almost completely suppressed; in one case in which the sputum was very offensive, carbolic acid caused the fœtor to disappear. In many of these patients the state of the respiratory organs improved. Two were cured. The rhonchi subsided or disappeared. Auscultation enabled me to state that parts in which no air circulated had become permeable. In cases of the second stage strength returned. One of these patients, who could scarcely get up one flight of stairs to my consulting room, walked more than a league (*lieue*, 2·8 miles) in the country a month later. Appetite was restored, and the patients could sleep without a calmative. After 15 or 20 days of this treatment the patients said that they felt re-animated, and their breathing was much more easy, the countenance indicating gaiety. Unfortunately, in all cases, amendment did not persist. After 2 or 3 months, cough and dyspnœa returned, and this time carbolic acid was powerless to effect their disappearance—yet life was prolonged. There is yet something unknown that an attentive study will perhaps permit me to discover. In cases of phthisis arrived at the last stage, that is to say, when the organic lesions and the general state foreshadow approaching death, the effects of carbolic acid were but slight. A slight increase of strength and diminution of cough and expectoration only may be observed. The difficulty of breathing remains nearly stationary. One patient only, *œtat* 17, with hereditary phthisis in the third stage, complained that the carbolic acid irritated and provoked cough. I was obliged to desist from using it. The inhalations of carbolised air lasted 3 to 5 minutes, and were practised from two to four times each day. For internal administration I have not exceeded 80 centigrammes (12·4 grs.)

daily, dissolved in 400 grammes (about 13 ozs.) of sugared water."*

I am sorry to add that my own experience has not corroborated these favourable results of M. Lemaire. I first employed carbolic acid in *moist* inhalations at the Royal Hospital for Diseases of the Chest, City Road.

The formula I adopted was the following:—

℞ Acid carbolic: liquid: ʒss.

to be added to a pint of boiling water, and the vapour inhaled. The inhalations were generally made night and morning. In some cases the patients expressed themselves as relieved, and especially said that after the inhalation they could obtain a good night's rest. I append a table of the results in 20 cases observed.

Cases.		
5 . . .	much improvement.	
7 . . .	relief	2 cases, relieved cough and disposed for sleep. 1 case, expectoration diminished.
3 . . .	doubtful, or no improvement.	
5 . . .	worse.	

1st stage of the disease.	3, much improvement. 2, no improvement. 1, slight improvement.		Hæmo-ptysis	2, continued. 1, diminished.
2nd stage	2, much improvement. 4, fair improvement. 3, became worse.		Cough generally	1, relieved. 2, unrelieved.
3rd stage	2, improvement. 1, doubtful. 2, became worse.			

In regard, therefore, to the inhalation of carbolic acid intermingled with the steam of boiling water, my conclusion is identical with that of Lemaire, viz., that the evidence is not favourable enough to encourage an extended use of the plan.

* De l'Acide Phénique, p. 615.

I then endeavoured to ascertain the value of *dry* inhalations of a carbolised atmosphere. These can be administered in several ways.

1. *Inhalation of the vapour proceeding from carbolic acid, mingled with air at ordinary temperatures.*—This is the plan of M. Lemaire before described. Concerning the probabilities of success of this plan several considerations present themselves. First, carbolic acid boils at a very high temperature; it is not conveyed to the lung, therefore, in any large proportions. For the inhalation to possess any influence, the agent must be conveyed to the lung surface in adequate amounts. We have seen that at a temperature of 50° F. about 177 cub. in. of air are required to take up 1 grain of carbolic acid; the proportion is increased at higher temperatures, so that at 60° F. 131½, and at 70° F. 77¼ cub. in. suffice to retain the same amount. But considering the quantity of carbolised air necessarily wasted in the process, the amount of carbolic acid really acting upon the lung-surface when this method is put in force must be small indeed. I tried the method in many cases of phthisis, but obtained no evidence of its possessing any value whatever.

2. *Inhalation of carbolic acid volatilised at heightened temperatures.*—I have adopted several methods of accomplishing this. The ingenious vaporiser of Messrs. Savory and Moore fulfils the indications in a most satisfactory manner. The expense of this, however, renders it impossible to recommend to all the patients in the out-patient department of a hospital, and there are many simple means of fulfilling the indications. The patients are supplied with a pure carbolic acid, liquefied by the addition of spirit, and are instructed to use half a teaspoonful of it twice or thrice daily in one of the following ways:—

An ordinary thick tea-cup or egg-cup is to be strongly heated in the oven or, in the absence of a fire, half a teaspoonful of spirit of wine is to be placed in the tea-cup, ignited, and allowed to burn till it becomes extinguished. Then, the cup being thus heated strongly, the liquid carbolic acid is poured

in a few drops at a time, whilst the patient inhales the resulting vapour.

Or a piece of metal, such as a penny, may be heated to redness, placed in a cup, and used as a hot plate on which to drop the acid.

The results, when this plan has been put in force, have been much more satisfactory than in the cases wherein the agent was inhaled at the ordinary temperature of the air. In some there was at first some provocation of cough; soon, however, tolerance was established: the immediate result was dryness of the fauces; but frequently patients whose coughs had previously been most troublesome were enabled to gain refreshing sleep. Certainly, the absolute quantity of expectorated matters was diminished and the fœtor corrected. The method was not adopted where there was any hæmoptysis.

As regards the permanent amendment of the phthisical condition by carbolised inhalations, I must speak with reserve. In all my cases other internal treatment was practised. I did not find any evidence of benefit when carbolic acid was administered internally; the evidence concerning the internal use of the sulpho-carbolates is given at a subsequent page. I look upon the employment of inhalations of carbolised air as a valuable adjunct to what may be termed the antiseptic treatment of consumption.

A case of extremely severe *purulent bronchitis* occurring in my private practice appeared to show in marked degree the influence of the treatment. The enormous amount of pus was greatly diminished, and the patient made an excellent recovery.

CHAPTER XXVIII.

THE EFFECTS OF CARBOLIC ACID INTERNALLY ADMINISTERED.

I. Poisonous Action of Carbolic Acid upon Animals. —In a former portion of this work it has been shown that carbolic acid, even when present in minute quantities, acts as a powerful poison upon the lower forms of animal as well as vegetable life. Its toxic effects are manifest in different degrees as the scale of complexity is ascended. An atmosphere containing carbolic acid suffices to kill a large number of the Articulata. M. Lemaire traced its action upon leeches, lumbrici, wood-lice, acari, spiders, myriapoda, pediculi, flies, gnats, fleas, bugs, ants and their ova, butterflies and their ova, caterpillars, crickets, cocci, cockchafers, earwigs, and other insects. These were all killed by a carbolised atmosphere; the smaller insects died in one minute, the larger insects and those possessing a horny external covering resisted longer the poisonous influence. Exposure to a carbolised atmosphere for a minute sufficed to kill the common round garden-worm.

If an insect were plunged into a weak solution of one part of carbolic acid in 1000 of water and immediately withdrawn, it appeared stupefied and as if paralysed, recovering itself gradually in the air. Molluscs, such as slugs and snails, died in one minute if placed in a 1-1000 aqueous solution of carbolic acid.

Fish, frogs, larvæ of aquatic salamanders, and leeches, died in a few instants in a saturated aqueous solution, but in weak solutions death took place slowly.

The following symptoms were noted in case of frogs. The anterior extremities were the first to become paralysed, then by degrees the animal became motionless. If, whilst in this condition, the animal were withdrawn from the poisonous liquid and placed in fresh air, the contractions of the heart, which had been suspended, returned in a few moments, but at distant intervals. As the carbolic acid evaporated, life seemed to return; but, though lingering for

an hour, the animal finally died. Sensibility was much impaired in the earliest stages of action while muscular action persisted. Suspension of heart's action took place during diastole.*

To observe whether the toxic action of carbolic acid in these cases was due to coagulation of the blood, MM. Lemaire and Gratiolet examined its influence on the branchiæ of the salamander when observed by the microscope. It was found that though circulation was immediately arrested, the shape of the blood corpuscles was unaltered—they became suddenly motionless.† The common experience of microscopic observers shows that weak solutions of carbolic acid produce no change on albuminoid tissues, only these are preserved in their pristine conditions.

When a 5 per cent aqueous solution of carbolic acid is administered to dogs the following symptoms are presented:—1. *Agitation:* The animal in a minute or two falls on its side, the muscles being convulsively twitched, cough occurs, and saliva runs from the mouth. 2. *Anæsthesia:* The sensibility of the skin is diminished, and in some cases perfect general anæsthesia is produced. The muscles also are paralysed. The carbolic acid is expired from the lungs, and is thus eliminated. The power of movement is gradually recovered; sometimes the anterior, sometimes the posterior, limbs are the first to recover. The toxic symptoms generally pass away in from 20 to 30 minutes; but the dogs remain weak and tottering, and do not absolutely recover till the end of 24 hours. The conditions observed when carbolic acid has been administered in a non-fatal dose (death being induced by opening the aorta) are especially —manifest congestion of the vessels of the brain, and in less degree those of the spinal chord.

The presence of olive oil or of albumen considerably diminishes the action of carbolic acid as given by the stomach; but the presence of glycerine greatly intensifies

* De l'Acide Phénique, pp. 61 *et seq.*

† *Loc. cit.*, p. 100.

that action, probably by disposing to a more complete and rapid absorption. When carbolic acid is administered in toxic doses to animals, there are found extreme congestion of the encephalon and its membranes, violet congestion of the mucous membrane of the alimentary canal, and extreme hyperhæmia of the lungs. The blood in the heart and large vessels remains uncoagulated. The muscles smell strongly of carbolic acid.

The following symptoms were noticed in the case of a mongrel greyhound :—" The animal was fasting. M. Bourrel caused it to swallow two grammes of pure carbolic acid dissolved in 50 grammes of glycerine. Dr. Prat was present. Less than a minute after the ingestion of this solution, the animal began to totter. Two minutes afterwards the hind quarters trembled, at the same time that the phenomena of intoxication increased, as shown by the irregular movements of this poor animal. It coughed, and, four minutes after the ingestion, fell upon the right side in convulsions. Six minutes after, the general sensibility was almost entirely abolished. The animal continued to cough, Frothy mucus, exhaling a strong odour of carbolic acid, escaped by the mouth. No evacuation of urine nor fœcal matter. Seven minutes after, abundant sweating. Cough and vomiting of sanguinolent froth. Eight minutes after, collapse succeeded the agitation. The dog died suddenly, ten minutes after the ingestion of the medicament." *

I caused a full grown cat to swallow about two drachms of the pure acid. Symptoms similar to those just recorded occurred with extreme rapidity. In addition the pupils became suddenly dilated, and death occurred in about two minutes; in fact, I never saw, with any agent, a cat so rapidly poisoned.

It was found that admixture with cheese entirely annulled the toxic action of carbolic acid. Albumen, which forms with the acid a white coagulum, also arrests its toxic action. M. Lemaire concludes that albumen can be

* Lemaire, De l'Acide Phénique, p. 83.

considered as the antidote for carbolic acid, and that in cases of poisoning it should be immediately administered.

II. **Poisoning by Carbolic Acid in the Human Subject.**—Cases of poisoning by the absorption of carbolic acid by the skin have been already considered. There have been, also, several instances in which death has resulted when this agent has been swallowed.

At the Derby County Infirmary carbolic oil was administered to a man, 64 years of age, in mistake for a dose of medicine. The quantity of pure acid taken was rather more than a drachm. In ten minutes the man appeared very ill. There were flushing of countenance, profuse perspiration, ineffectual vomiting, the eyes rolling wildly. The mucous surfaces of mouth, tongue, and throat were whitened by contact with the agent. The means attempted for restoration were—mustard emetic, stomach-pump, administration of albumen, injection of castor-oil. After an hour mental equilibrium seemed restored, pyrexia and retching continuing; and there were epigastric pain and tenderness. The symptoms of gastritis deepened, and continued until nine hours after the ingestion, when collapse supervened, and death took place in three hours—twelve hours from the poisoning. Mr. Anderson, the house surgeon, in recording the case, considers, with much apparent reason, that the symptoms arose "from the direct effect of the acid upon the parts with which it came in contact, reacting upon a constitution enfeebled by age and a previous severe accident." There was no post-mortem examination.*

A case of poisoning by impure carbolic acid occurred at the Surrey County Lunatic Asylum, Brookwood. To a woman of 30, hemiplegic, about 1½ ozs. of the crude acid were administered in mistake for a senna draught. Immediately intense burning pain down the œsophagus and stomach was experienced; the mucous membranes were seen to be whitened. In a few minutes speech became stammering and the patient tottered, then insensibility

* Lancet, January 30, 1869, p. 179.

supervened. The following were the means for attempted restoration :—Swallowing being impossible, the contents of six eggs were introduced into the stomach by means of the stomach-pump; afterwards magnesia mixed with water was introduced, and the viscus washed out. Breathing became more stertorous; artificial respiration induced temporary amendment. Pupils seemed insensible to light; pulse frequent, small, thready, and intermittent. Death took place a little more than one hour after the ingestion.

The most noticeable post-mortem appearances were—extreme congestion of the vessels of the brain, the contained blood being of the consistency of tar. The liver, spleen, and kidneys, when incised, smelt strongly of carbolic acid; the kidneys were congested. The mucous membrane of the œsophagus and stomach was congested, especially at the cardiac end; in the latter a green stain was noticed. The chief points of interest summarised by Mr. Swain, in his report of the case, are—(1) the rapidity of the fatal symptoms, probably superinduced by the brain lesion and previous habits of intoxication on the part of the patient; (2) the detection of the odour of carbolic acid in most of the internal organs—in this way Mr. Swain thinks a poisonous dose administered feloniously might be detected; (3) the rapid way in which the poison had passed through the pylorus, probably by the induction of paralysis of the muscular fibres, the intestine being full of the brownish red fluid; (4) no decomposition had occurred where the carbolic acid existed, the parts not locally acted upon contrasting strongly with those penetrated by the antiseptic; (5) the green stain of the stomach, which might have been due to the special action of the acid on the stomach normally acidulated with hydrochloric acid.*

A third case of poisoning, also by the crude acid, is recorded by Dr. Barlow, of Manchester. A man of about 60, who had been drinking heavily for some days, was heard suddenly to fall, and was discovered frothing at the mouth,

* Lancet, March 20, 1869, p. 395.

speechless, and with turgid countenance: before the arrival of medical aid the man was dead. A bottle, which had contained about an ounce of a fluid supplied for the purpose of sprinkling the floors for driving away cockroaches, was said to have been near deceased, but subsequently to the death it had been thrown away; only the post-mortem examination, therefore, could explain the cause of death. The post-mortem signs noted were—engorgement of vessels of the surface, the visible mucous membranes whitened; vessels of the scalp gorged with dark blood; brain pale; stomach contracted, contained about an ounce of turbid pinkish fluid smelling of carbolic acid; coats of stomach much thickened; mucous membrane elevated in ridges, like those upon the palate of an ox, hard and whitish on the summit; pyloric extremity pinkish, but comparatively unaffected; in intestines no trace of local effects of the agent; œsophagus as the stomach, but in less degree; the mucus in masses, white, and loose, coming away with a touch. Dr. Barlow was led to infer "that the man, upon waking from his slumber, with the raging thirst so likely to follow a debauch, saw the bottle near him and mistook the contents for spirits, and the fluid, entering an empty stomach, seized upon and corrugated the coats of that organ in the manner before stated, and the consequent shock and depression caused almost immediate death."*

In another case, recorded by Mr. F. Sutton, Resident Medical Superintendent of the Borough Asylum at Norwich, a female, aged 43, swallowed an ounce of crude carbolic acid in mistake for black draught. Five minutes afterwards she was insensible, with contracted pupils, face blanched and bathed in perspiration, respiration stertorous. She died within an hour and a half of the ingestion. The treatment consisted of the application of the stomach-pump, which was with difficulty passed down the œsophagus. The autopsy showed whitening of the mucous membrane of the mouth. The stomach manifested dry white patches on the

* Lancet, Sept. 18, 1869, p. 404.

surface of its rugæ; the mucous membrane could be readily peeled from its walls.*

Dr. Wiltshire relates a case in which a youth of 19, suffering from enteric fever, swallowed a tablespoonful of the crude acid administered in mistake for a dose of mixture. The patient never rallied, but death did not occur until after the expiration of two days. Treatment consisted in administering milk and bland fluids. A lividity and a mottled appearance of the skin were noticed; the characteristic blackness was communicated to the urine.†

Dr. Ogston, of Aberdeen, records the case of a man, aged 47, who swallowed in mistake about an ounce and a half of the crude acid. He was unconscious, and the symptoms simulated those of apoplexy: the pupils were contracted to the size of a pin's point, and after a short time there was no muscular movement. Five and a half hours after ingestion slight movement returned, and partial consciousness. Then dyspnœa, with muco-purulent expectoration, occurred. Urine having the dark characteristic appearance was passed; it smelt of carbolic acid. Collapse set in, with clammy sweat. Death took place thirteen and a half hours after ingestion.‡

Many other cases have occurred, the details of which are less complete. The "British Medical Journal"|| notices one, in which a carman drank carbolic acid from a two-gallon stone bottle, in mistake for beer. Death occurred in a few hours, after much suffering.

Mode of Action of Carbolic Acid as a Poison.—The evidence shows that the toxic action of carbolic acid is two-fold—direct and local, absorbed and systemic. Its powerfully poisonous action upon the lowest forms of life is manifest. This is not due to its property of coagulating albumen, for even from *batrachia* upwards the blood is found

* Med. Times and Gazette, April 25, 1868, p. 456.

† *Ibid.*, October 22, 1870, p. 474.

‡ Brit. Med. Journal, Feb. 4, 1871, p. 116.

|| Sept. 17, 1870, p. 310.

after death uncoagulated, and the blood corpuscles are not visibly changed. That it has a profound effect upon the nervous system is obvious; the nerves of the surface of the higher animals are first irritated, subsequently anæsthetised. It is probable that, in the case of the low forms of life, there is a direct action upon the protagon. Obviously its direct and local effects upon the surface constitute but a small part of its action, for not only are its internal effects much intensified when it is administered with an agent such as glycerine, which diminishes its topical action, but symptoms of its systemic action are manifest from its diadermic absorption.

The early effects of its systemic absorption in the higher animals are manifest upon the nervous system. From the flushings, the congestion of the surface, and the induction of sweating, it would appear that the vaso-motor nerves are paralysed. The prominent symptoms are those of intoxication; these may be induced by doses which are not poisonous. Lemaire has noted cases in which children of eight years of age have presented symptoms of stupor after the administration of an injection containing 50 centigrammes of the agent. Some people are much more susceptible of its influence than others. A child of three who had taken 20 centigrammes in sugared water was violently excited; and another of eight presented the same symptoms after taking 30 centigrammes. A patient suffering elephantiasis, who took about 3 grammes per diem, suffered headache, vertigo, and tingling of the fingers and toes. Another patient after the ingestion said, it always made him feel intoxicated.* The chemical constitution of the agent, itself an alcohol, affords a reason for its intoxicating power. It is absorbed into the current of the blood and projected throughout the system; it is observed that elimination of it takes place chiefly by the pulmonary surface, but the kidneys in part share this action; these are rendered hyperhæmic, and the excreted agent is in certain cases to be detected in the urine.

* LEMAIRE, De l'Acide Phénique, p. 95 *et seq.*

The most pronounced effects of the absorbed poison are upon the blood supply of the nerve-centres—these, especially in their venous channels, are found to be engorged with blood. Another effect of the toxic action of carbolic acid is upon the lungs, inducing hyperhæmia. This is not observed in all cases, but especially in those in which the progress of poisoning is more slow or else where the agent is mingled with glycerine, whereby it is rapidly diffused through all the structures. Where the symptoms are *foudroyants*, where the brain-implication is the chief, these are less evident. A dog belonging to M. Flourens died of pneumonia three days after the injection of three grammes of carbolic acid. Lemaire considered that probably the disease existed before the administration, but this appears to be very doubtful. In a dog which died ten minutes after the administration of 2 grammes of carbolic acid mixed with 50 grammes of glycerine, the lungs were found to be congested, especially the left, which was engorged with red blood. Lemaire adds:—"Cet état était evidemment le résultat de l'action de l'acide phénique. Cette lésion était toute récente."* In a horse to which 50 grammes of carbolic acid in aqueous solution had been administered, and which was killed two hours afterwards, the lungs were found ecchymosed in several points.† The reason of the pulmonary hyperhæmia is not far to seek. The great channel for the elimination of the carbolic acid is the pulmonary surface. In those cases in which death has not occurred before an attempted elimination, congestion of the lungs, on which the labour of excretion is thrown, is therefore probable. The respiratory difficulties in the cases of poisoning in the human subject were probably of twofold origin—partly due to a cerebral, partly to a pulmonary cause.

The whole data show that in the fatal cases of poisoning in man, the agent has manifested its effects partly as a

* De l'Acide Phénique, p. 84.

† *Loc. cit.*, p. 94.

local irritant, whereby the symptoms of acute gastritis have been induced, partly as a specific poison, having pronounced and determinate effects upon the internal organs.

Toxicological Data.—It is to be remarked that carbolic acid is one of the most powerful of poisons. Great care should be enjoined in its use; this fact should be impressed upon all who use it as a disinfectant. It can cause death even when it acts only upon the skin; particular care should be taken when children are likely to come in relation with it. It should never be sprinkled upon the floors or upon any surface likely to be used as a seat unless it be in perfect solution in water. Directions have been given for obtaining this perfect solution. The facts have shown that it has frequently been swallowed in mistake for beer or spirits. The provisions of the Poisons Act should be put in force in relation to it.

The *signs indicating poisoning by carbolic acid* are especially the whiteness of the mouth, tongue, and fauces, induced by the local action upon the mucous membrane, and the characteristic odour. The symptoms have been already indicated.

The *treatment of cases of poisoning* should be conducted upon the following principles:—There are three objects in view—first to render inert and to remove the acid which remains in the stomach; secondly, to antagonise the effects of the poison already absorbed; thirdly, to relieve the symptoms of local irritation. The first of these indications is fulfilled by the administration of a substance with which carbolic acid forms an insoluble compound. The best substance to employ—one which can be considered a veritable antidote to carbolic acid—is *albumen.* Oil has been recommended, but this possesses less advantages, its union with carbolic acid is less stable, it is less readily miscible with the stomach contents, and if any be retained it gradually gives up the carbolic acid, and can thus prolong, though it at first diminishes, the toxic effects. The first thing, therefore, to be done in a case of carbolic acid poisoning is to

administer the whites of as many eggs as can be conveyed into the stomach, and this by the natural powers of swallowing, if possible, if not by means of the stomach-pump. Emesis should be provoked with as little violence as possible, and fresh whites of eggs again administered.

The next indication is to aid the elimination of the poison, which is rapidly absorbed. The chief eliminating surface is the pulmonary. It would appear to be advisable to cause the patient to breathe a warm steam-impregnated atmosphere; in some cases artificial respiration would be called for. Seeing the extreme congestion of the intra-cranial vessels in the fatal cases, it would seem very possible that venesection, especially of the external jugular, would be attended with benefit. For the purpose of directly neutralising the acid whilst it is circulating in the blood, we have as yet no sufficient data to guide us to the choice of an agent. As we have seen, the simple combinations of carbolic acid are so unstable that they would be useless to this end. It is just possible that the administration of dilute sulphuric acid might tend to the formation of the harmless sulphocarbolates within the system, but on this point investigation is necessary. One thing is, however, certain, that nothing should be given by the stomach which can by any possibility be irritating to the mucous membrane already suffering from the caustic effects of the carbolic acid. Nutritive enemata should be administered which could be acidulated with dilute sulphuric acid. If the case were protracted after the disappearance of the special signs of carbolic acid poisoning, it should be treated as one of acute gastritis.

Characteristic Post-Mortem Signs of Carbolic Acid Poisoning.—A case has already been cited showing the importance of an identification of these signs in relation to jurisprudence. The signs upon which most reliance can be placed are—(1) the peculiar odour of the acid; (2) the white appearance of all the mucous membranes over which it has passed, the contracted condition of the stomach, with ridge-like elevations of its mucous coat;

(3) the arrest of *post-mortem* decomposition in the tracks of the acid.

In all cases the parts in which carbolic acid is supposed to be present should be submitted to chemical investigation.

Owing to the firmness with which carbolic acid unites with albuminous substances, its chemical detection in the viscera is far from easy. With the kind assistance of Professor Tuson and Mr. Neison, of the Royal Veterinary College, I have endeavoured to investigate the best mode of detecting carbolic acid in the tissues in toxicological enquiry. The results are as yet incomplete; but the following appears to be the best mode of procedure :—The viscera are macerated in (*a*) an aqueous, or (*b*) an alcoholic, solution of potassium hydrate. The filtrate is divided into two parts. One part is carefully neutralised with sulphuric acid, then mingled with a little saliva, and a few drops of oxidised tincture of guaiacum added. The production of the bluish-green colour indicates the presence of carbolic acid. To the other part of the filtrate, excess of strong nitric acid is cautiously added, and after standing for some time it is well boiled. Thus the carbolic is converted into picric acid, which is evidenced by a few drops of the liquid giving the characteristic coloration to a large bulk of water, and by its property of dyeing a strand of silk yellow, while a strand of cotton immersed in it remains uncoloured. The perchloride of iron test is inoperative when carbolic acid exists with organic matter.

CHAPTER XXIX.

THE INTERNAL ADMINISTRATION OF CARBOLIC ACID IN DISEASE.

I. **Diseases of Animals.**—In illustrating the properties of carbolic acid as a means of antagonising the poisons of infecting diseases, we have already considered the evidence adduced by Mr. Crookes and Mr. Hope, which tended to show that carbolic acid, when administered to living animals suffering from cattle plague, modified the disease by shortening its duration or by inducing an absolute cure.* Further observations confirm the conclusions concerning the therapeutic value of the agent in other infectious diseases of cattle. In the Texas cattle disease, it is asserted that carbolic acid was used *intus et extra* with great success. The formula adopted was—Carbolic acid, 12 fl. ozs.; glycerine, 4 fl. ozs.; bicarbonate of soda, 12 ozs.; to be mixed together. Two tablespoonfuls administered for a dose mingled with three or four gallons of water.† There is also evidence to show the success of the administration of carbolic acid to cattle suffering from the highly-fatal *malignant pustule*. In this case the evidence seems very circumstantial. A Commission appointed by the French Academy of Sciences, consisting of eleven members, M. Bouley being President, reported that, although every animal which had been experimentally inoculated with anthracic disease died without a single exception, when carbolic acid was administered to animals similarly inoculated, four out of five recovered. In the case of sheep, 1 gramme of the acid was employed for a dose; in oxen 10 grammes; it was given in a one-per-cent aqueous solution. Of four sheep treated three recovered, and in the other the usual duration of the disease anteriorly to death was prolonged. One young bull thus treated recovered. M. Missonier also successfully treated two cows

* See p. 134.

† Third Annual Report of Metropolitan Board of Health of State of New York.

which suffered from the anthracic disease contracted naturally. It is added that a man and child both affected with malignant pustule, and in an extremely dangerous state, "were saved by the employment of carbolic acid administered externally and internally." M. Lemaitre used the same method of treatment in five horses attacked with anthracic disease, and all five recovered.*

Of course caution must be exercised in drawing positive conclusions from these data, but there are certain points to be elicited from them which seem to have a deep signification. Besides the direct evidence pointed by the recoveries (in Mr. Hope's cases of cattle plague and the cases of anthracic disease cited by the French Commission) in diseases which were collaterally proved to be almost uniformly fatal, there are to be noted (1) that the natural course of the diseases has been modified under the influence of the treatment adopted. This is shown (*a*) in Mr. Crookes's cases by the thermometric observations. Observations show that in cattle plague there is a progressive increase in the sensible temperature of an animal; injection of carbolic acid into the blood of diseased animals was uniformly followed by a depression of temperature; (*b*) under the carbolic acid treatment the normal duration of the disease was prolonged. In Mr. Crookes's cases, the mortality, which usually occurred at latest on the fourth day, was prolonged until the sixth. A like protraction was observed in anthracic disease, as recorded. (*c*) The evidence showed that there might be a quantitative relation between the therapeutic agent and the curative effect. Treatment which was unsuccessful in restoring cattle when the agent was used in the proportion of less than one part to 10,000 of their blood, was successful when it attained this proportion; (*d*) lastly, the pathology which has been enunciated in former chapters fitly and rationally explains the therapeutic properties of the agent. In the diseases in question there exist organised particles in the blood. In anthracic disease occurs that decomposition

* Comptes Rendus de l'Acad. des Sci., 1869, pp. 82—86.

of the blood even during life which we have traced to be the function of organised (fungoid) particles to produce. Nay more, by observations direct (the microscopic investigations of Davaine, Stiles, and others), and indirect (Hallier, Semmer, and others), these organised particles are proved abundantly to exist in the blood. We know it to be the property of carbolic acid to *kill* these organised particles, and to arrest the decomposition which they induce. Present in sufficient proportions carbolic acid accomplishes this and arrests the disease which is the result of their presence.

II. Diseases of Man.—Carbolic acid has been administered in disease in several different modes. The French authorities, as M. Lemaire, generally prescribe it plentifully diluted with water, the proportion of the acid to water being 1 to 1000. Lemaire's formula is—Water, 1 litre; crystallised carbolic acid, 1 gramme; dose for adults, 1 litre a-day. It can be administered as an ordinary mixture by adding glycerine or spirits of wine to favour its diffusion. The dose of the liquefied acid is usually from 1 to 6 minims; the proportion of alcohol or glycerine being equal to that of the acid. Since carbolic acid forms combinations with albumen, fats, and various alimentary principles, it should not be given soon after a full meal. Lemaire says that honey should not be substituted for crystallised sugar in the medium in which it is administered. The commencing dose recommended for young children by Lemaire is 10 centigrammes (about $1\frac{1}{2}$ grains) dissolved in 60 grammes of sugared water (about 3 tablespoonfuls). In adults the commencing dose should be 50 centigrammes (about $7\frac{1}{2}$ grains) to be taken dissolved in 2 tumblerfuls of sugared water night and morning 4 hours after a meal and 2 hours before the next. It must be impossible to follow this indication in many cases wherein food must be administered at frequent intervals. The dose can be increased to 3 grammes ($46\frac{1}{4}$ grains) per diem; generally, however, 1 gramme (about $15\frac{1}{2}$ grains) each day is advisable. Lemaire discourages the administration of carbolic acid in the form of pills, because these may irritate locally the mucous membrane of

the stomach. The following are described as *contra-indications* to the internal employment of carbolic acid, viz., acute affections of the nervous centres and of the lungs. When the central nervous system or the pulmonary tract is congested or inflamed, carbolic acid aggravates the condition. It aggravated the symptoms in a case of bronchitis with emphysema.*

The effects of overdoses of carbolic acid have been already mentioned. Dr. Fuller notices the occurrence of a giddiness and fulness, or peculiar feeling in the head—a feeling which occurred in some persons within 2 minutes after taking the acid, and in others not until the expiration of 6 or 8 minutes. In some this giddiness passed off in 10 or 15 minutes, and in others it lasted nearly an hour. In no instance was there any distinct headache or any interference with vision; but when the giddiness was over there were in some instances cold clammy perspiration and feeble pulse. Of the physiological action of carbolic acid Dr. Fuller makes the following interesting observations. "In health, the only effect which was observed to follow moderate doses—4 to 6 minims—was the production of a peculiar greenish tint in the urine, and the disappearance of all deposits of lithates. Both these phenomena were most marked when full doses—8 or 10 minims—were given, and in themselves were very remarkable. The intensity of the greenish tint varied considerably. Apparently it was more influenced by the state of the urine than by the mere dose of the acid; but the disappearance of the lithates from the urine bore a tolerably constant ratio to the dose of the acid, so that, if the administration of 4 or 5 minims failed to produce the desired effect, the addition of 3 or 4 minims to each dose would in most instances accomplish it within 3 or 4 hours. Indeed, carbolic acid proves so powerful an agent in clearing the urine of lithates, that it will operate with tolerable certainty in cases in which moderate doses of alkalies fail altogether in checking the deposit. It does not increase or

* LEMAIRE, De l'Acide Phénique, p. 412.

diminish the secretion of urine, nor does it appear to exercise any influence on its specific gravity; it does not affect the action of the bowels, though it diminishes the offensive odour of the motions; it has no effect on the temperature of the body, nor does it influence the pulse, except when it is given in excessive doses and excites giddiness and cold perspiration, and then the pulse is accelerated. Having remarked the uniformity of the action of the acid in checking the deposit of lithates, and thinking that possibly it might control the formation of lithic acid, I administered it in full doses in several cases of gout. It certainly rendered the urine clear, but it did not appear to modify the gouty action or check its continuance. The same may be said of its action on rheumatism." *

The real nature of the effect produced upon the urine is an interesting question. This has already been briefly considered. Opinions have been conflicting as to whether the appearance is due to the escape of the colouring matter of the blood, or to the carbolic acid itself eliminated in a changed form. On this point we have the following evidence:—(1) There is no direct relation between the degree of toxic action of carbolic acid and the peculiar coloration of the urine; the latter is met with in cases which present no sign of discomfort from absorption of the acid, and this for protracted periods. Nor is any deviation from the healthy standard of the urine passed in quantity or quality to be noted. Although in some cases, after death from carbolic acid poisoning, there has been hyperhæmia of the kidney, this is far from being a constant sign. (2) Though the peculiar greenish tint produced by the absorption of carbolic acid is often evident to the eye, the coloration is rendered much more distinct upon the addition of nitric acid and the application of warmth; then a reddish-chocolate colour appears, commencing often as a granular precipitate much resembling blood. I have observed this in cases in which carbolic acid has been applied to the surface, though the

* British Medical Journal, Feb. 20, 1869, p. 161.

urine before the addition of the nitric acid and the application of heat presented no abnormal character whatever. (3) The addition of strong nitric acid to an aqueous solution of carbolic acid causes a deep brown colour. I have found that if a small quantity of an aqueous solution of carbolic acid be added to urine, and afterwards a little nitric acid, no change is induced; but if the whole be heated, a deep red coloration appears, closely resembling that induced in the case of the urine of carbolic acid absorption. There can be little doubt, therefore, that the greenish hue, the seeming hæmaturia, in cases in which carbolic acid has been absorbed, is really due to the agent itself in a stage of oxidation, and that the coloration induced by nitric acid and heat is evidence direct of excretion of carbolic acid itself. We come now to the practical employment of carbolic acid in certain diseases.

Dyspepsia.—Dr. Fuller speaks of its value in fermentive dyspepsia; this is, as might be expected, of its action as an antiseptic; administered in 6 or 8 minim doses, it stimulates and is extremely grateful to the stomach; it causes an immediate evacuation of flatus, and by checking fermentation it puts an end to the evolution of gas, which forms the most distressing feature of many varieties of dyspepsia. "With the exception of charcoal," Dr. Fuller adds, "I know of no remedy so useful in these cases, and it not unfrequently operates beneficially when charcoal fails to relieve."* Dr. John Harley, however, has not found that it annuls the production of *sarcinæ ventriculi*. Dr. Garraway found it a good remedy in one drop doses in the sickness of pregnancy.† Dr. Wilks also finds it of use generally in sickness, and Dr. Andrew Clark has found it preferable to creasote, especially where there exists either fermentation or gastric catarrh. The last observer says that it is of value, especially when combined with morphia, in irritability of stomach. In pyrosis it has cured when

* Carbolic Acid: its Doses and Medicinal Value; Brit. Med. Journal, Feb. 20, 1869, p. 161.

† *Ibid.*, p. 235.

other means have failed. I have not myself found that it has any marked value in the dyspepsia of phthisis.

Cholera and Diarrhœa.—During the latest outbreak of cholera it was said that carbolic acid was administered with success. Dr. Andrew Clark considers it of no use in cholera, but thinks it is certainly useful in diarrhœa, both when given by the stomach and administered in enemata.* M. Lemaire publishes a successful case of employment of injections containing carbolic acid in dysentery.†

Enteric Fever.—Dr. Andrew Fergus, of Glasgow, adduced a case in which half grain, afterwards increased to two-third grain, doses of carbolic acid administered every three hours to a child less than two years of age, suffering from severe enteric fever with extreme diarrhœa, appeared to do much good. In less than 24 hours the character of the stools was changed; they became much darker in colour, and of a more consistent nature. The case, though apparently hopeless, recovered. In two other cases it seemed to render the course of the disease comparatively mild. It is but just to say, Dr. Fergus quoted these cases as suggestive, not conclusive, of the value of carbolic acid in enteric fever. Lemaire employed the agent in typhoid fever, but with no success. Dr. Murchison also found it of very little value, though it seemed to relieve the tympanitis and diarrhœa. Dr. Wallace considered that in typhoid it had no good effect, and in one case it seemed dangerous; nor did it prevent the septic poisoning and irritative fever subsequent to typhus. Dr. Buchanan is sure that carbolic acid has no influence on the specific course of typhus, enteric fever, or scarlatina.‡ Dr. Fuller, coincides in this opinion.‖ Considering its action in inducing congestion of the brain, &c., it seems scarcely likely that this should be an appropriate remedy in typhus.

Intermittent Fever.—Drs. Barraut and Tessier, of the Mauritius, have testified to the value of the administration

* Brit. Med. Journal, Feb. 13, 1869, p. 146.

† De l'Acide Phénique, p. 532.

‡ Brit. Med. Journal, Feb. 13, 1869, p. 145.

‖ *Ibid.*, p. 161.

of carbolic acid in malarious fever. It was employed in two modes—(1) internally in grain doses, with a little brandy or bitter infusion; (2) hypodermic injection of from 12 to 20 minims of a solution of 64 grains of the pure acid in 4 ounces of water.* Dr. Tessier reports, that of 30 patients treated by the hypodermic injection of from 20 to 40 minims of the solution just mentioned, the injection being repeated daily (sometimes twice daily) for three days, two-thirds of the cases were cured.† Other observers, as Mr. E. C. Mackey, have failed to confirm these results.‡ In these cases 5 minims of carbolic acid were administered internally every four hours. It would appear quite unnecessary to administer carbolic acid by hypodermic injection, when it is so rapidly absorbed from the skin-surface when applied externally mingled with oil or glycerine, or other such vehicle.

Scarlatina, Measles, and Small-Pox.—Dr. Alex. Keith, of Normanby, in a communication to the "Lancet," of Jan. 22, 1869, calls attention to a successful mode of treatment of these zymotic diseases by the internal administration of carbolic acid; 600 cases were treated, with five deaths. The dose of pure carbolic acid administered was from about 4 to 6 minims, the adjuncts being acetic acid, tincture of opium, chloric ether, and water (see Appendix). Dr. Keith gives no sort of classification of his cases, so that it is impossible to arrive at any just appreciation of the value of his treatment. He believes that the physiological effects of the carbolic acid treatment are—(1) profuse perspiration; (2) rapid lowering of the pulse and subsidence of pyrexia; (3) cleansing of tongue and diminution of soreness of throat; (4) increase of appetite. Not all these signs accord with those which we have observed as those characteristic of carbolic acid, the diaphoretic effect, for example. Dr. Keith notices the darkened urine as an effect of the carbolic acid.

Small-Pox.—M. Chauffart employed carbolic acid in this disease with evidence of much success; 15 grains freely

* Lancet, January 23, 1869, p. 136.

† British Medical Journal, September 18, 1869, p. 428.

‡ Lancet, May 15, 1869, p. 671.

diluted were given in the 24 hours. In five severe cases rapid decline of fever and arrest of suppuration in the vesicles occurred. A lotion of carbolic acid (1 to 100 or 150 of water) was also applied to the surface from the first appearance of the eruption.* Application of carbolic acid to the pustules of small-pox to avoid the usual disfigurement was early practised by M. Lemaire. He used the strong acid liquefied by alcohol. In a case narrated wherein about ten pustules were left untouched for the purpose of comparison, in 24 hours after the carbolic application a complete desiccation occurred, whilst the untouched ones were still filled with pus. Even if employed solely to prevent disfigurement which results from small-pox, this is, as M. Lemaire says, a most valuable application.† I am in a position to confirm his results. I have myself applied carbolic acid to the small-pox pustules with the effect of not only a drying-up of the pustules and prevention of subsequent pitting, but a great and immediate increase in comfort to the sufferer. It is much better to lightly touch each pustule with strong carbolic acid, liquefied by water, alcohol, or acetic acid, than to apply a carbolised lotion to the whole surface.

Chronic Bronchitis.—Lemaire speaks of surprising results attending the employment of carbolic acid in chronic bronchitis.‡ He has recorded five examples in which great benefit resulted from the administration of carbolic acid in aqueous solution. In the first case, the first dose induced relief, and the cough completely disappeared after three days' treatment, though it had persisted two months without alleviation. In a second case, a child of 8, who suffered cough for six months, three days' treatment procured complete cessation. In a third case, a chronic bronchitis of about four months' duration, complete arrest of cough and expectoration resulted after two litres of "eau pheniquée" had been administered. In a fourth case, *ætat* 64 (chronic

* Gaz. Med. des Hôpitaux Union Medicale, 1870.

† De l'Acide Phénique, p. 688.

‡ *Ibid.*, p. 469.

bronchitis with asthma), the carbolised water was used as a gargle, as well as an internal remedy. The cough rapidly disappeared, and in twelve days had quite ceased. In many cases I have myself seen favourable results from the administration of carbolic acid in bronchitis; of my belief in the good effects of dry inhalation I have already spoken. My experience, however, is not so extremely favourable as M. Lemaire's. Dr. Andrew Clark also thinks the employment of carbolic acid in chronic bronchitis and bronchorrhœa to be of great value, both internally (in half grain doses dissolved in water) and locally in the form of inhalation or spray.* Dr. Fuller has used the spray in chronic bronchitis, and in gangrene of the lung with beneficial effects.†

Hooping Cough.—Lemaire has quoted cases which seem to have presented very favourable results after the administration of carbolic acid internally, and the impregnation of the surrounding air with the vapour. The supposed good effects of the vapours from gas works are well known. It has been suggested that the idea had its origin in the employment of carbolic acid. I have tried the internal administration of the remedy in a large number of cases of hooping cough in children. In a few cases the influence seemed direct and salutary. As I before said, I am convinced of the value of the local application of a carbolised lotion or liniment to the chest. I am of opinion, however, that this value is chiefly attributable to its local sedative effects. As an internal remedy for hooping cough, it is still *sub judice*.

Phthisis.—Lemaire administered carbolic acid in twenty cases of phthisis; in the second and third stages the external administration was combined with the inhalation before noted. The amount internally administered in each case did not exceed 80 centigrammes (rather more than 12 grains) per diem; it was given in sugared water. These have already been considered in the chapter devoted to

* British Medical Journal, Feb. 13, 1869, p. 145.

† *Ibid.*, p. 160.

INHALATIONS. As I have before said, I have not met with any direct evidence of the advantage of the internal administration of carbolic acid in phthisis. Moist inhalations containing carbolic acid also appeared to me to be unattended with advantage; but of dry inhalation of carbolised air I have had sufficient experience to convince me of the real value.

Constitutional Syphilis.—Mr. Garraway, of Plymouth, has recommended the administration of carbolic acid in syphilis. In two cases of old standing, which had resisted all the usual methods of treatment, he prescribed 5 minim doses of the *Glycerinum acidi carbolici* (P.B.) in 1½ ozs. of water three times a day, the dose being gradually increased to 10 minims. In the course of a few weeks all signs of secondary eruption had disappeared.

Resumé.—Concerning the mode of action of carbolic acid when administered internally, we have much to learn; our data are, as yet, insufficient. From our knowledge of the nature and properties of the agent, and from the observations as to its effects, toxic as well as therapeutic, we may gain certain ideas as to its action. This is probably compound—(1) it has a *local action* on the mucous membrane of the alimentary canal. We may fairly infer this from its action on mucous membranes generally. It is probable that the relief of atonic dyspepsia, which has been observed, may have been due to this property. This action would be at its maximum when the agent is administered in the form of pill, or in a not bulky aqueous medium, and at its minimum in the case of admixture with glycerine, or in those extreme dilutions (1 to 1000 of water) prescribed by Lemaire; (2) from its volatility it is most probable that it is in part distributed in the form of vapour by the internal heat; (3) it may manifest its action on the contents of the stomach; from the freedom with which it enters into combination with organic bodies, and the consequent modification of its properties, it is most probable that the action is influenced by the presence and the quality of food in the stomach at the time of its administration; hence,

Lemaire advises it to be given only when the stomach is empty. Yet, from its power, which many attest, of ameliorating fermentive dyspepsia, and from its known power of preventing fermentive change outside the body, it is likely that it manifests an action upon the alimentary contents of the stomach; it is probably thus mainly that it influences fermentive dyspepsia. But from experience derived from its action outside the body, especially when we consider that only a portion of the ingested carbolic acid can really mingle with the food (some acting locally, some uniting with organic products, some becoming absorbed), it seems to me that the quantity commonly administered is insufficient to produce very pronounced effect upon the stomach contents. And it is not surprising that the *sarcinæ* in Dr. Harley's case escaped the toxic effect; (4) there is no doubt that the carbolic acid is absorbed from the alimentary canal into the blood; its mode of action when thus absorbed presents much analogy with that of alcohol. It is eliminated by the kidneys and by the lungs, it may induce hyperhæmia of the former, but this is certainly not its usual action, and the appearances of the urine, so suggestive of hæmaturia, are merely the harmless evidences of its own excretion in the form of a pigment. It would appear very probable that its efficacy in chronic bronchitis, to which much evidence points, is due to its effect upon the lung-capillaries, as it is determined to them for excretion.

CHAPTER XXX.

THE ANTISEPTIC TREATMENT OF ZYMOTIC DISEASES.

In the foregoing pages the action of carbolic acid and its position among other agents of its class have been considered. It has been shown that, according to the highest probability, carbolic acid owes its remarkable power of arresting putrefactive decompositions to its power as a poison to minute

particles which possess vitality. The evidence has traced the first causes of transmissible disease to vitally-endowed molecules similar to those which induce in dead organic matter metamorphic decomposition ; and the phenomena of disease to the changes induced upon the living body by their analogous growth, multiplication, and hence the altered chemistry and changed conditions, of the animal mechanism.

If our view of the nature of transmissible disease be correct, what bearing does it possess upon the great science of therapeutics ? According to our views, the following must be the natural history of such diseases. The vitalised molecules rapidly multiplying in the fluids or tissues, or proceeding therein to a higher degree of development, arrive in course of time at one of the following crises :— either having lived their term of life they die, the natural pabula surrounding them sufficing no longer for the maintenance of their vitality ; or the induced conditions or the secretions of the animal fluids are rendered such as to become fatal to them ; or the eliminating processes of the body get rid of them. Thus the disease, that is to say, the compound results of the acts of vitality of the organised molecules, and the systemic disturbances which are superinduced, ends in recovery. Or else the molecules persist in their vitality, and consequently in their destructive agency, upon the living structures, and death ensues. The first practical requirement, therefore, would appear to be to arrest the vitality of those molecules which are considered to be the prime causes of all the changes. Yet it must be acknowledged that such a problem is not uncomplicated ; for in the first place the vitality of the contained organisms may have proceeded far before their noxious influence is declared by obvious signs ; and, in the second, the induced organic decomposition of the body may be such as to be a prominent and persistent source of evil independently of the cause which originally induced it. Nevertheless the chief problem would appear to be how to arrest the destructive influence of the living agents. We shall then be led to enquire whether it is possible to destroy within the living

body vitalised molecules, which common experience tells us we can destroy outside the living body. That such a thing has no *primâ facie* impossibility is shown by the fact that we are frequently employing internal remedies to destroy entozoa, having far higher vital endowments than the *Micrococci* of putrefactive changes. Furthermore, we have evidence to show that the very substances which we have been accustomed to administer in zymotic diseases, have themselves great power as antiseptics or destroyers of germs. Foremost amongst these is alcohol, which Hallier places next to benzin and carbolic acid in antiseptic power.* Of the agents mentioned as capable of destroying organised particles outside the body a very large proportion is capable of absorption into the blood. Saccharine fermentation we have considered to be due to fungoid organisms, *Micrococci* developing into *Cryptococci*, and these into *Mycelium*. I have myself determined experimentally that the fermentation of 2 fluid drachms of brewers' yeast, mixed with 25 grains of sugar, and placed in circumstances the most favourable for the process, is wholly arrested by the following;—Liquor hydrargyri bichloridi, $\frac{1}{2}$ a drachm; tincture of the perchloride of iron, 5 minims; sulphite of soda, 5 grains; sulphuric acid 1-10th grain. It is needless to say that these remedies have frequently been used in diseases due to contagion, and it is reasonable to infer that some of their success may have been due to their property as septicides. Nevertheless, it was with no idea that such was the mode of action of these substances that they were thus employed. In 1857, Professor Polli, of Milan, introduced a series of agents, with the avowed object of withstanding the internal decomposition occurring in zymotic disease. It was not supposed, however, that these agents influenced living septic agencies; they were rather considered as opposing the catalytic changes supposed to occur according to Liebig's theory of fermentation and zymosis. These agents were sulphurous acid, and the sulphites and hyposulphites of the alkalies and alkaline earths.

* Cf. Hallier, Gährungserscheinungen, p. 94.

It was found that animals could, without any apparent ill effects, swallow and absorb large doses of the sulphites. It was then observed that when the animals were killed they long resisted the putrefactive process—that whilst an animal killed under ordinary circumstances exhibited rapid and marked signs of putrefaction, an animal which had previously absorbed doses of the sulphites betrayed no sign of putrefaction whatever. Another series of experiments, and in this series three hundred dogs were the bases of the deductions, showed that the sulphites exerted a prophylactic and curative power when septic poisons were introduced into the economy.

Then, as regards the human subject. It was found that the stomach would tolerate large doses of the sulphites of soda or magnesia. They were tried in the various eruptive fevers, intermittents, typhus, typhoid, pyæmia, puerperal fever, dissection wounds, malarial infection, &c. The records of cases treated in this way show an extraordinary amount of success. Dr. Polli states—" I published my first memoir on this subject in 1861, and since that time one hundred and fifty-eight papers have been published in answer to my call; and, with the exception of five or six containing some criticisms on my labours, all the remainder confirm, in the strongest terms, by many hundreds of detailed observations, the value of these remedies."*

I can endorse this statement from my own personal experience. I have employed the sulphite of soda in the eruptive fevers, in malignant sore throat, in diphtheria, as well as in cholera and choleraic diarrhœa. In measles I have used it in a number of cases, always with apparent success. In scarlatina I have employed it, both internally administered and as a gargle; its efficacy in anginoid symptoms has been marked. In diphtheria I have employed it in like manner in three cases. These were all extremely severe; all but one recovered, the fatal case being a child of two years, to whom none of the sulphite was for twenty-four hours, by a mistake in the nursing, administered. In

* British Medical Journal, November 16, 1867.

a case of small-pox the effect seemed to be pronounced. The face was completely covered with pustules, the drug not being administered till the pustular stage had arrived. There was extreme prostration; the pulse was, on November 7th, 1866, 104: the sulphite of soda, in scruple doses, was assiduously administered every four hours, and in two days the signs of danger passed, the pulse falling to 76 on November 9th. I notice that Dr. Nichol, in the "Nashville Journal of Medicine and Surgery" for August, 1866, testifies to the efficacy of the sulphites in small-pox. For cases illustrating the value of the sulphites in cholera and choleraic diarrhœa, I can only refer to my own volume.*

If it be granted that the sulphites are useful in the infecting diseases, what is their *modus operandi?* In my answer to this question I am forced to differ from Professor Polli, who says, "these salts do not act as poisons towards the several morbific ferments. . . . They do not kill the catalytic germs of the organic poisons; but they re-act on the material components of our own organism, rendering it, by their presence, incapable of being acted on by these catalytic germs."† The mode in which Polli supposes they affect the "fermentable stuff" of the organism is a process of deoxidation.‡

Before discussing this proposition, we will turn to *à priori* considerations as to the power of agents absorbed into the blood to arrest septic changes, without compromising the vitality of the higher organism which contains them. Is it probable that such agents could be administered in sufficient quantities?

Professor Claude Bernard said—"We cannot neutralise these ferments in the living organism—it is impossible, because to effect such a purpose, it would be necessary to interfere with the character of the blood to such an extent, that it would be no longer capable of maintaining

* The Arrest and Prevention of Cholera.

† British Medical Journal, November 16, 1867.

‡ See Medical Times, May 5, 1866.

life." Here it is to be observed, first, that Bernard embraces the zymotic theory *in toto.* He readily admits the existence in the blood of morbid ferments, but denies our power of neutralising them without also deteriorating the blood. And what is his reason? No doubt he thought when he penned the foregoing sentence that a neutralising agent would act by chemical means. Now, I readily admit that if sulphurous acid or the sulphites acted merely as deoxidising agents, to neutralise the ferment, it would be necessary gravely to interfere with the character of the blood. But I have said that these agents do not solely or chiefly act by virtue of their chemical power. They act by arresting the vitality of the lowest forms of organised particles. Moreover, there are many arguments against Polli's hypothesis that the sulphites act not on the ferment but on the pabulum, wherein the ferment undergoes development. In the first place what does physiological chemistry tell us concerning the action of sulphites in the economy? Dr. de Ricci says, "Animals after having been saturated with sulphites were killed, and every portion of their body, solids and fluids, gave, on examination, unquestionable proof of the presence of the sulphites employed. These experiments seemed to prove that when sulphites, whether alkaline or earthy matters or not, are introduced into the stomach of a living animal, they may be absorbed and circulated *as such* through the organism."* Furthermore, "Dr. Polli found in men, as in dogs, that they are not ordinarily decomposed in the stomach, but pass unchanged into the blood, or, at least, appear in a brief period unchanged in the urine, and only after a while as sulphates."† From these facts alone it may be concluded that the deoxidising power of the sulphites must be limited indeed, for that power could be strictly determined by their transformation into sulphates. Furthermore, if the efficacy of the sulphites depended on their deoxidising power over the fluids of the organism, consider

* Glasgow Medical Journal, October, 1865, p. 297.
† Medical Times, May 5, 1867.

what an enormous quantity would be required to effect such an object! What does analogy teach us? A trace of sulphurous acid or an alkaline sulphite will arrest the fermentation of a large quantity of saccharine material. The same quantity would not suffice to deoxidise the smallest fraction of this material; therefore, its efficacy must lie in some other quality than its power of deoxidation. Analogy tells us that it has a peculiar power, as I have before stated, of arresting vitality. There is nothing antagonistic to reason in the conclusion that substances which are perfectly harmless in the case of a high organism should be fatal to a lower organism. Common salt, among a multitude of others, presents an instance in point. I think, therefore, we cannot fail to come to the conclusion that the sulphites are readily absorbed by the higher organisms—that they circulate in the economy for the most part unchanged—that they exert a peculiar power, not upon the pabulum of the body, but upon organised particles which may exist within it; and that in virtue of this septicidal power, they manifest those prophylactic and curative effects which both experiment and experience have proved them to possess.

The great lesson left by the experience concerning the sulphites, then, appears to be, that a living being can absorb, without the manifestation of any deleterious effect, a quantity of an agent which evidence obtained externally to the body convinces us is capable of arresting the putrefactive changes in a large bulk of decomposing material, by killing the organised molecules which are the agents of such decomposition.

These observations as to the mode of action of the sulphites pertain with increased force to carbolic acid. We have seen what a powerful restrictive influence this exerts on putrefaction, and how persistent is its action. It would seem, therefore, that in carbolic acid we have an excellent agent for internal administration in transmissible diseases.

It behoves us, however clearly, to put before ourselves the objects which we desire to accomplish in the employment of antiseptic medicines in disease. In the first place

the conditions are not uniform; they vary with the portions of the economy subject to the septic influence. For example, if, as possibly in some cases of diarrhœa and cholera, there is a disintegration effected by the means of organisms of the lining of the alimentary canal, an agent is called for which shall as powerfully and persistently as possible antisept the surface of the lining of the canal. In such case an agent which can be rapidly absorbed into the blood is comparatively undesirable. On the other hand, where there is blood-poisoning by septic agency, the first requirement is an agent which can be absorbed as rapidly as possible.

What are the general properties of carbolic acid determining its value as a therapeutic agent for internal administration? That it is absorbed into the blood is abundantly proved, not only by the experience of its internal administration, but by the facts of its manifest toxic action in some cases, both of the human subject and of animals, when it has been externally applied. Its action, however, as a poison, shows its danger when a too great amount of it exists in the blood in a given time. Its faculty of inducing hyperhæmia of the nervous centres suggests its cautious use in cases wherein these are in a more than ordinarily susceptible condition. Carbolic acid can be administered in three modes—the pure acid mixed with bread or other vehicle in the form of a pill, the aqueous solution, or various mixtures and combinations with other substances. When it is administered pure, we know that it must have a strong local action on the mucous surfaces with which it comes in contact; this caustic action would probably present a difficulty as to its own absorption by a self-imposed barrier. Its aqueous solution would seem to be the most satisfactory way of exhibiting it, but unless it is highly diluted, it is still a powerful irritant of sensitive surfaces. Moreover, it is exceedingly nauseous, and almost impossible of administration to young children. Lastly, as we have seen, it is peculiarly facile in its combinations, forming different compounds with albumen, alcohol, glycerine, fats, &c., each

having different degrees of action. So it is probable that the effects would vary, not only with the medicinal adjuncts with which it is administered, but with the nature of the contents of the stomach at the time of administration. It is obvious that, granted the correctness of the germ theory of disease, the problem of its treatment by antiseptic medication is a complex one. Though very much concerning the probable value of a given antiseptic agent may be deduced from physical investigation, the chief evidence must be the actual results when it is administered in the various conditions of disease. Practical, or to use the favourite expression of the day, *clinical*, experience is the greatest test on which to rely.

It must be acknowledged that in cases wherein the zymotic influence is most manifest upon the blood, an antiseptic which shall be readily absorbed is the greatest desideratum. The sulphites have this advantage, but their efficacy has been denied by many. I personally hoped that experience with the compounds of carbolic acid might point to an agent more efficient still. The simple salts of carbolic acid, the carbolates, seemed to present no advantage over carbolic acid itself, so readily were the combinations displaced. Administering a carbolate had the same disadvantages as administering carbolic acid.

It had been known that equivalent weights of carbolic acid and sulphuric acid combined to form a stable sulpho-carbolic acid, which presented some analogies with sulpho-vinic acid. My friend, Mr. Crookes, succeeded by neutralising this acid with potash, in producing a crystalline salt — sulphocarbolate of potash. To Mr. Crookes undoubtedly belongs any merit which may attach to the inauguration of this enquiry. From the ready solubility and not unpleasant taste of the sulphocarbolate of potash, I thought, with him, that it afforded an indication towards the discovery of a valuable practical antiseptic for internal administration.

I then devoted myself to the preparation and investigation of the various sulpho-carbolates of the alkaline and

metallic bases, and I succeeded in producing a series of definite double salts. In the prosecution of the enquiry I have to acknowledge the valuable aid which I have received from Messrs. Balmer, and their assistants, Messrs. Anthony, Davison, Smith, and others. They have not only laboured indefatigably to prepare the salts in a state of great beauty and purity, but have efficiently assisted me in all steps of the enquiry. We prepared the sulpho-carbolates of the alkalis in September, 1867; the sulpho-carbolate of zinc was obtained by us in a state of great purity in July, 1868, and we have recently succeeded in preparing the sulpho-carbolates of most of the other metals.

CHAPTER XXXI.

THE SULPHO-CARBOLATES.

Sulpho-Carbolic Acid (Syn. Sulpho-phenic or Phenyl-Sulphuric Acid, $C_6H_6SO_4$ or $C_6H_5SO_4H$) is the compound acid resulting from the union, in equivalent proportions, of hydrated sulphuric acid and pure carbolic acid. Heat is evolved in the combination, the temperature being raised to 200° F., and the immediate result is a syrupy fluid which slowly deposits crystals. By slow crystallisation at low temperatures the pure sulpho-carbolic acid may be obtained in long, slender, colourless needles, which readily deliquesce in the atmosphere. It may also be obtained by exactly decomposing the barium sulpho-carbolate with sulphuric acid, filtering from the insoluble barium sulphate, and evaporating *in vacuo*.

Sulpho-carbolic acid has a sp. gr. of 1·288; its odour resembles that of carbolic acid, but is less intense; heated to 400° F., it becomes of a bright red colour, and, when cooled, is nearly solid; it boils at 540° F., and at 560° is decomposed into a black amorphous, inodorous mass. Nitric acid added to sulpho-carbolic causes immediate decomposition with violence.

Sulpho-carbolic acid is soluble in water, alcohol, and ether, in any proportions. Its solution reddens litmus, and gives, like the aqueous solution of carbolic acid, a beautiful mauve or purple colour, on the addition of a solution of a per-salt of iron. The reaction is much more manifest in the case of the double acid than in the case of carbolic acid itself.

Mode of Preparation.—The calculated proportions of each of the acids necessary for the production of the sulpho-carbolic are 94 parts by weight of carbolic acid and 98 parts of hydrated sulphuric acid. It is found necessary in practice, however, that the sulphuric acid shall be in excess. It is better to use 120 weight parts of the latter to 100 of the former. The mixed carbolic and sulphuric acids should be kept at a heat of 240° F. for a quarter of an hour, and then allowed to crystallise. It is advisable to wait two or three days for the combination to be thoroughly accomplished. The supernatant liquid should then be poured off, and after heating to 150° F., set aside for further crystallisation. The accumulated crystals are dissolved in pure water, and barium hydrate added till the excess of sulphuric acid ceases to fall as barium sulphate. The liquid decanted from the precipitate contains pure sulpho-carbolic acid.

The Sulpho-Carbolates are prepared from the pure acid thus obtained by saturation with various oxides.

Barium Sulpho-Carbolate, $Ba(C_6H_5SO_4)+3Aq$, is prepared by adding to the sulpho-carbolic acid diluted with ten times its bulk of water, barium carbonate. It is not necessary for the preparation of this salt to free the sulpho-carbolic acid previously from the excess of sulphuric acid, for by the addition of the barium carbonate, this is precipitated as barium sulphate, together with the excess of the carbonate employed. The filtrate is to be slowly evaporated by heat and allowed to crystallise.

The resulting barium sulpho-carbolate is in colourless rhombic prisms, tending, like the other sulpho-carbolates, to cohere in spheroidal groups. It is very readily soluble in watér and in alcohol.

Sodium Sulpho-Carbolate, $Na(C_6H_5)SO_4+Aq$, is obtained

by carefully neutralising the pure sulpho-carbolic acid dissolved in at least six volumes of water with carbonate of sodium or caustic soda. The neutral di-sodic carbonate gives the best results. The resulting solution should be slowly evaporated over a sand-bath or water-bath until a pellicle appears upon the surface; it should be then set aside to crystallise. To obtain good specimens re-crystallisation from a solution in pure water should be practised.

The resulting salt is in brilliant colourless rhombic prisms, having the characteristic tendency to cohere in rosettes, freely soluble in six times its bulk of cold distilled water and in two-thirds its weight of boiling water; it is slightly soluble in alcohol, but not in ether. A strong heat drives off a portion of the carbolic acid, and an aqueous solution of the residue gives the reactions of sulphuric acid; at a red heat it is consumed without flame.

The pure salt is singularly tasteless, only possessing a very slight bitterness.

Potassium Sulpho-Carbolate, $K(C_6H_5)SO_4+Aq.$, is prepared in a mode similar to that described for the sodium salt, neutralising the sulpho-carbolic acid with potassium carbonate or hydrate.

The crystals are in rhombic plates, clear and colourless, very easily soluble.

Ammonium Sulpho-Carbolate, $NH_4(C_6H_5)SO_4+Aq.$, is obtained by neutralising with ammonium carbonate or ammonium hydrate (liq. ammoniæ). It crystallises usually in the form of rectangular plates, and generally resembles the potassium salt.

Magnesium Sulpho-Carbolate, $Mg(C_6H_5)SO_4+Aq.$—Prepared in an analogous manner from magnesium carbonate, is usually a mass of small brilliant crystals, but by careful crystallisation it may be obtained in fine rhombic prisms. It is very soluble.

Calcium Sulpho-Carbolate, $Ca(C_6H_5)SO_4+Aq.$—By neutralising with calcium carbonate (pure precipitated chalk), this salt is obtained in a congeries of needle-shaped or feathery crystals of a brilliant white appearance, the interlacing

network forming an exceedingly light spongy mass. It is soluble in its own weight of cold water.

Zinc Sulpho-Carbolate, $Zn''(C_6H_5)SO_4+7Aq$.—To prepare this salt pure sulpho-carbolic acid may be saturated with zinc oxide, or pure zinc itself may be used, hydrogen escaping in the decomposition. Or, to a filtered solution of 10 parts of barium sulpho-carbolate in three or four times its weight of water, a solution of six parts pure zinc sulphate dissolved in three times its weight of water may be added. A slight excess of zinc sulphate should prevail so as to completely precipitate the barium. The filtered solution is evaporated and allowed to crystallise.

Zinc sulpho-carbolate forms brilliant colourless rectangular plates, very soluble.

Copper Sulpho-Carbolate, $Cu(C_6H_5)SO_4$.—It is prepared by neutralising with cupric oxide. It forms brilliant prisms of an emerald green colour.

Iron Sulpho-Carbolates.—It is probable that iron forms two distinct compounds with carbolic acid.

Ferrous Sulpho-Carbolate, $Fe(C_6H_5)SO_4+Aq.$, is prepared by acting on pure iron with sulpho-carbolic acid to neutralisation and evaporating.

It exists in rectangular plates of a very pale green colour. The presence of a small quantity of a per-salt of iron in a solution of ferrous sulpho-carbolate causes a deep purple or mauve colour. The earliest sulpho-carbolates of iron prepared were all tinged with this colour, but the pure protosalt as now prepared is almost colourless. It is probable that the deep colour is due to the presence of

Ferric Sulpho-Carbolate, though this has not been satisfactorily isolated.

General Characters of the Sulpho-Carbolates and Tests.—Each sulpho-carbolate should possess a definite and decided crystalline form, and should be perfectly transparent, entangling no organic *débris*. They should possess scarcely any odour of carbolic acid. All should yield perfectly clear solutions. These solutions should give no precipitate with barium chloride. If a few crystals be

boiled for a few minutes with nitric acid and then twice the bulk of water added, picric acid in yellow glistening scales is thrown down, and the supernatant liquid gives a white precipitate with barium chloride, showing that sulphuric acid is liberated. If to a solution of a sulpho-carbolate a drop of solution of a per-salt of iron be added, the clear liquid assumes a beautiful purple or mauve colour. One-sixtieth of a grain of sodium sulpho-carbolate is capable of inducing the mauve tinge in a ferric solution. The sulpho-carbolates are all very stablc compounds.

Therapeutical Employment of the Sulpho-Carbolates.

As *direct* antiseptics the sulpho-carbolates do not occupy a high place. They are far less efficient than many other salts of the metals, especially the chlorides and sulphites. The sodium salt is, *quoad* the amount of carbolic acid it contains, twenty times less efficient as an antiseptic than free carbolic acid itself. Carbolic acid, when it forms compounds with organic bodies, has its antiseptic power impaired by such combination, and this appears in a direct ratio with the stability of the compound it forms. The very unstable carbolates possess, for the amount of carbolic acid they contain, equal antiseptic power with carbolic acid itself; not so the sulpho-carbolates, which are compounds of great stability. It may be concluded that the direct antiseptic power of carbolic acid in a given compound is inversely as the stability of the compound.

Comparatively with the other sulpho-carbolates, the sodium sulpho-carbolate manifests the chief power in arresting saccharine fermentation. As this salt is, even in a strong solution, exceedingly tasteless, it was chosen for internal administration.

Two guinea-pigs were fed with pills composed of arrowroot mixed with sodium sulpho-carbolate. No other food was given. In four days the little animals consumed 275 grains of the salt. No obvious effect was produced, exccpt a slight looseness of the cvacuations. The animals being killed, and examined after death, there was found to

be no morbid lesion, but the duodenum of one contained an unusual quantity of yellow bile. On chemical examination the muscular tissue, the liver, and the urinary bladder yielded sodium sulphate; but neither sulpho-carbolic nor carbolic acid was evident to tests. The flesh showed a marked tendency to resist putrefaction.

It was found that 20 grain doses of sodium sulpho-carbolate could be readily administered to adults. So free from taste was the solution, that many said it seemed only like water itself. The dose was increased in several cases to 60 grains administered every four hours. The only direct effect noted was a slight tendency to vertigo or dizziness. The odour of carbolic acid could be readily detected in the breath. The urine of a patient who had taken 360 grains of sodium sulpho-carbolate in twenty-four hours was collected and examined. It presented no evidence of the presence of carbolic acid, but contained a considerable quantity of sodium sulphate. It showed a marked tendency to resist putrefaction.

It would appear, therefore, that sodium sulpho-carbolate administered to a living animal is rapidly absorbed and projected throughout the system. In the blood, or the tissues, the double salt is decomposed, the sodium sulphate being set free in the tissues, and ultimately excreted by the kidneys; the carbolic acid also liberated in the textures eventually, for the most part, escaping by the lungs. It is probable, also, that some portion of the carbolic acid is eliminated by the urine. It follows that the administration of sodium sulpho-carbolate is an indirect means of administering carbolic acid; and, inasmuch, as at least one fourth of the weight of the sulpho-carbolate employed consists of carbolic acid, we find that an amount equalling from 15 to 90 grains per diem can be administered of the latter. It is obvious that the direct administration of this amount of carbolic acid would, from its nauseous character and its difficulty of manipulation, be not readily accomplished; and there would be a danger of the toxic action of the latter being manifest, a result which does not occur when the sulpho-carbolates

are administered. One would imagine that in this latter case there is a gradual evolution of carbolic acid, which at no time is in sufficient amount to manifest its poisonous action.

For evidence of the action of the sulpho-carbolates in disease we turn to the evidence of actual experience.

I. Sulpho-Carbolates of Alkali Bases.

Of these the *sodium sulpho-carbolate* has been the most largely employed.

Dose.—The usual dose for adults has been ℈j every three or four hours; in some cases it has been increased to ʒss or ʒj. For children of seven years of age 10 grains has been a usual dose.

The following results have occurred in my own practice when sulpho-carbolate of sodium has been administered.

Ulcerative Tonsillitis.—In 21 cases thus treated the throat symptoms completely disappeared, leaving perfect power of swallowing in 4 cases in 3 days, in 13 cases in 4 days. The remaining cases were not observed till the end of 7 days—they were then quite well.

Some of these cases were in persons subject to such attacks in which suppuration was the usual course. In none of the above was there any suppuration: the fauces rapidly lost their hyperhæmia, and if ulceration had commenced, cicatrisation was rapid. In one of these cases a gentleman, subject to attacks of suppurative tonsillitis, experienced all the signs of his usual ailment, prostration, high fever, and great swelling and redness of both tonsils. No suppuration occurred, and in three days the patient was well and able to go to business. In another case of severe tonsillitis of the form usually accompanied by profuse suppuration, the evidence appears remarkably suggestive.

Mr. M., aged 56, sent hurriedly for me on February 8th, 1871: symptoms of throat distress, with inability to open the mouth, salivation and high fever commenced the day previously and increased with great rapidity. From my

former experience in analogous cases, I was enabled to state that under treatment by the sulpho-carbolate of sodium, there was great probability that the throat-distress would subside after the lapse of four days. I prescribed half a drachm of sodium sulpho-carbolate in cinnamon-water every three hours. On the day following, however, the patient was much worse, and his relations feared a fatal termination. I myself felt that the case was critical. I was induced to examine the medicine dispensed from my prescription. Evaporated in a teaspoon it left no residue whatever. I caused it to be examined by a chemist who found it to consist wholly of cinnamon-water, *without a trace of a sulpho-carbolate.* Thus, by the culpability of the chemist, twenty-four hours were lost. The treatment being commenced in earnest the patient passed through his extreme peril of pyrexia, delirium, prostration, and violent throat-distress. On the fourth day after treatment there was complete relief; the patient, for the first time speaking in his natural voice, told me he felt as if his illness had been a matter of a year ago. All inflammatory sign had passed away. His recovery was uninterrupted. *One week from the date of the first symptoms,* he walked to my house and back to his home (more than a mile) with perfect ease.

Sloughing Ulceration of Tonsils.—The following are brief notes of three cases :—

1. John C., 7 years 6 months ; observed after three days' fever with ashy slough over right tonsil. Ordered 10 grains sulpho-carbolate every four hours. Progressive improvement in all respects. Seventh day of treatment ulcerated surface nearly cicatrised. Patient feeling almost well. Perchloride of iron substituted.

2. Mary B., 7. Great prostration ; large ashy slough covering left tonsil, enlarged superficial glands, and tumidity of neck. Ordered 10 grains sodium sulpho-carbolate every four hours. Third day of treatment slough gone ; thin layer of pus over ulcerated surface. Pulse 160. Temp. 106° F. Regular and progressive improvement. Tenth

day greatly better; fourteenth day able to walk: mucous membrane of throat perfectly healthy.

3. Amy A., 13, delicate child; observed after four days' sore throat. Large ashy slough covered right tonsil. Pulse 124. Temp. 102·4°. Ordered 15 grains sodium sulpho-carbolate every four hours. Second day of treatment: throat distress extreme; delirium. Pulse 140°. Temp. 105° F. Fourth day, ashy slough evident on *left tonsil also*; no delirium. Pulse 112. Temp. 100·5°. In the evening could swallow bread and butter. Sixth day slough entirely disappeared; tonsils enlarged, but no inflammatory redness. Power of swallowing perfect. Pulse 96. Temp. 95·4°. Eighth day, no perceptible enlargement of glands of neck. Tenth day, no other sign than debility. Perchloride of iron substituted. Progress uninterrupted.

Scarlatina.—The following is an analysis of 29 cases, some of which were of extreme severity. In one case, a boy of 7, there had occurred a sudden subsidence of rash, which had previously been profuse; epileptiform convulsions; much tumidity of neck and extrusion of discoloured mucus from the nose. Temp. 105° F. As soon as subsidence of convulsion permitted swallowing, 15 grains of sodium sulpho-carbolate administered every alternate hour. Following day improvement, rash profuse, throat signs severe. Temp. 103·6°. Fourth day perfect power of swallowing; child sat up and amused himself with painting. Recovery uninterrupted and uncomplicated.

In a second case, manifesting profuse rash, the signs of prostration which had been marked at the onset subsided, so that the little girl (aged 7) during the pyrexial stage while the rash was fully out was permitted by her parents to run about the room and play with her toys. In this case the most profuse desquamation followed.

The mean temperatures in a third case, wherein the throat signs were very severe, were—sixth day of fever, 104° F.; seventh day, 105°; ninth day, 101°; eleventh day, 97°.

On December 4th, 1870, Mr. White, of Dalston, requested

me to see with him a case of scarlatina of extreme severity. I can best describe the symptoms by quoting from a letter from Mr. George White to myself. "On the 2nd, severe throat symptoms set it; the tonsils covered with sloughs of an ash colour; the glands externally much enlarged. The child remained almost insensible; he could be roused by being spoken to loudly, but immediately resumed his insensible condition. This case had not been treated by carbolic acid until seen by you, when 15-grain doses (of sulpho-carbolate of sodium) were ordered every four hours, and the body covered with a solution of carbolic acid in oil, the patient being kept up with beef-tea, brandy, &c. No improvement on the following day; in fact, the case appeared hopeless, the child being roused with more difficulty. On the next day, the enlarged glands decidedly smaller; the child more sensible; the tongue looking slightly more moist, and the swallowing improved. From that day a steady improvement until the 11th day, when paralysis of the right facial nerve came on, which yielded to a course of iodide of potassium. The child has now perfectly recovered."

The throat symptoms passed away, leaving perfect power of swallowing in 9 cases in 4 days. Complete convalescence took place in 9 cases in 7 days; in 3 cases in 11 days; in almost all the others in 14 days. The only sequelæ observed were in one case, albuminuria appearing in one day and disappearing in the next; in one case general anasarca, which recovered; in one case abscess of a superficial gland in the neck; in one case a small persistent glandular swelling without suppuration; and in one a small abscess a month afterwards, all treatment having been omitted after 7 days, the child being considered by its parents well.

In only one case was there a fatal result. This was in a child *ætat* 9 months, presenting the maculæ of hereditary syphilis. Three grains of sodium sulpho-carbolate every 4 hours, commenced on 3rd day of fever, temperature being 103° F. Child seemed to improve till 4th day afterwards,

when screaming occurred with diarrhœa (Temp. 105°), and death.

It is not pretended that the argument from the numerical data can be considered as unanswerable. It at least, however, affords a *primâ facie* argument in favour of the treatment. So far as general impressions can guide to a correct conclusion, the treatment has appeared far more satisfactory than any other which has been put in force. Collateral records show that the general rate of mortality, at the same periods, of the same diseases has been greatly more pronounced; though for precision it would require a wider basis for observation than the number of cases recorded. But it must be acknowledged that there is other evidence afforded by this series. It is to be recollected that in all these cases, beyond the usual dietetic treatment, no other drug was administered except the sulpho-carbolate dissolved in pure water, nor was any topical treatment whatever practised. It is, therefore, fairly to be inferred that if anything interfered with the natural history of the disease it was the sulpho-carbolate, and the sulpho-carbolate alone. There seems to be an agreement in the evidence that the natural course of the disease was interfered with (1), by a curtailment of its duration; (2) by a subdual of the pyrexial conditions; (3) by a most obvious alleviation of the throat symptoms, one of the cardinal troubles of the disease.

Three cases of *erysipelas*, two of which were phlegmonous and very severe, have been treated by the sodium sulpho-carbolate. On the eighth day of treatment all febrile signs had passed away in each case, and recovery was rapid.

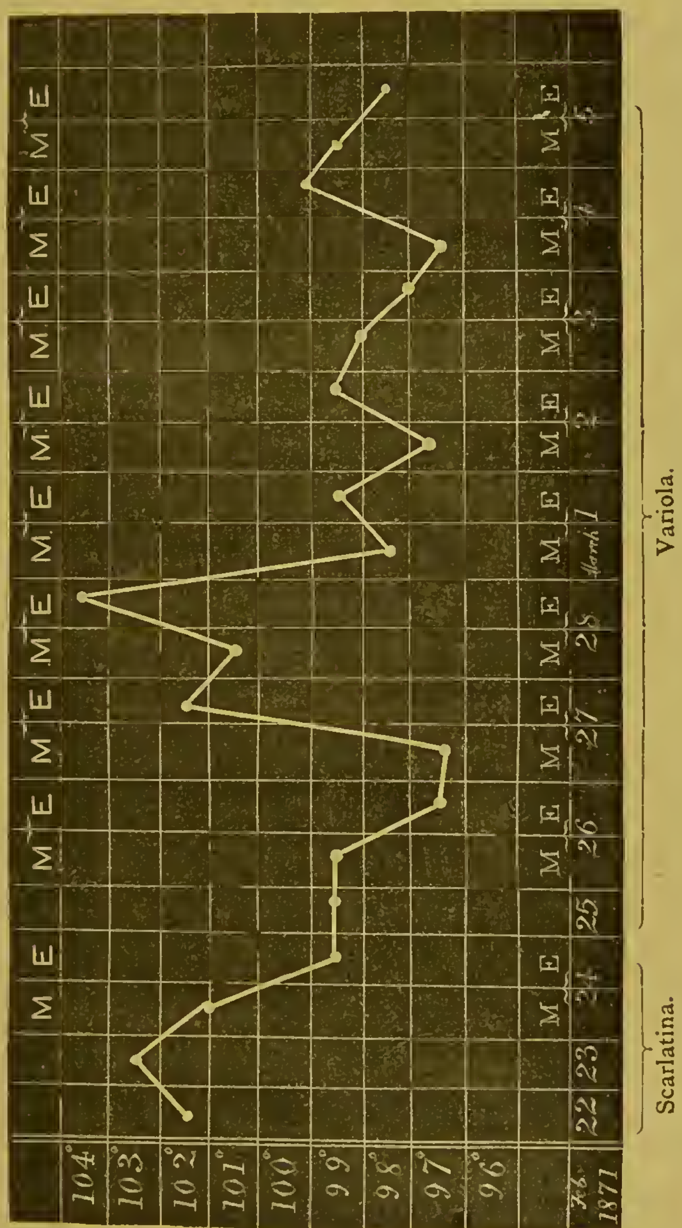
Variola.—My experience of cases of variola treated by the sulpho-carbolates is insufficient, as regards the number observed to allow of any conclusion, of which *numerical* data constitute a part of the premisses. The intrinsic evidence of the cases themselves, however, seem to point very strongly the probability that the sulpho-carbolates may be extremely valuable agents in the internal treatment of the disease; and the pathology of the disease would

seem to forcibly indicate the probability that their agency might be favourable. Six cases, two of which were unvaccinated (the only ones in which I had opportunity of employing the agent), recovered most satisfactorily. The unvaccinated cases present very slight traces of pitting. One of the vaccinated cases, sister of one of the unvaccinated, had a most formidable attack of the disease, partially confluent, but recovered perfectly. One case (said to have been vaccinated in infancy, but with very imperfect cicatrices), presented unusual symptoms, which seemed to indicate the coexistence of scarlatina and variola.

A Sister of Mercy, aged 31, in active duty in a district in which both scarlatina and variola were rife, was re-vaccinated without success on February 13th, 1871. On February 16th and 17th occurred rigors and lumbar pain; on the 21st, sore throat. She then came under my notice. There were much pyrexia and tonsillar ulceration, and the throat had a scarlatinal look. On the 22nd, I saw her in bed, covered with rash exactly resembling scarlatina, and with the precise throat-signs of the disease. On the 23rd, the rash was persistent, with purplish petechiæ scattered over the chest. She manifested great prostration. On the 24th, the rash was persisting; but papulæ of variola covered the face and thighs, the arms and hands; there were rather fewer on the chest. The tongue was loaded with thick fur. During the next four days there were urgent distress, insomnia, subdelirium, and sore throat, but very little implication of the external glands. The variolous spots became confluent on the face and thighs. On the 28th, there was defervescence; the pustules, previously full of matter, desiccated and fell off, leaving brown stains, but scarcely any pitting. The treatment consisted, for the first three days, of 20 grains of sulpho-carbolate of sodium every four hours; subsequently, half a drachm of the sulpho-carbolate with a grain of quinine every four hours. She was ordered beef-tea and milk, and six ounces of brandy daily. As soon as the pustules were fully formed,

they were individually brushed over with liquid carbolic acid once each day for three days, a weaker solution (5 per cent) being also applied night and morning. Recovery was most complete and satisfactory.

CHART OF TEMPERATURE.—CASE OF SCARLATINA AND VARIOLA.



I am disposed to think this a genuine instance of scarlatina and variola occurring together in the same patient at the

same time. I had a case presenting a probability of the same conjunction in a member of the same sisterhood in 1868. In this there was a distinct history of the communication of scarlatina by wearing apparel; and at the same time the patient experienced a fright on seeing closely a boy just recovering from severe small-pox. Here there were all the usual signs of scarlatina, with abundant rash. On the second day of initial symptoms, there was lumbar pain; on the tenth, varioloid papules, few in number, which followed the course of modified variola. The scarlatinal symptoms were in this latter instance much the more formidable of the two affections. A third instance of a similar conjunction, occurring in the country, has been narrated to me.

I am of course well aware that occasionally variola is ushered in by a roseoloid rash. The two cases previously cited, however, present many points of difference from variola roseolosa. There are (1) a plausible history of the double contagion; (2) a definite history of scarlatina, with the usual throat-signs; (3) a varied relation of intensity in the correlated diseases in the two instances—in the one case the variola, in the other the scarlatina, being the more pronounced. Again, the thermometric signs in the first case (a chart of which is appended) were peculiar—very different from the usual history of the pyrexia of variola. There appear to be two waves—one for the scarlatinal, the other for the variolous period.

The treatment appeared most successful. At one period the case seemed hopeless. The defervescence was little less than extraordinary. Under the local influence of the carbolic acid, the desiccation and decadence of the pustules were rapid and complete. Exactly three weeks from the onset, the patient was well, and able to be transferred to the country.

Enteric Fever.—Dr. Ligertwood, of Newbury, has employed the sodium sulpho-carbolate, in conjunction with quinine, in an epidemic of severe typhoid. Twenty-four cases were treated with three deaths. A table of the cases compiled by Dr. Ligertwood is appended.

SULPHO-CARBOLATE OF SODA IN ENTERIC FEVER.

THE CASES OCCURRED IN NEWBURY, BERKSHIRE, IN 1869.

No.	Sex.	Age.	Onset of Fever.	Convalescent.	Died.	Previous health.	Violence of Fever.	Complications.
1	F.	6	May 20	June 5	—	Good.	Severe.	
2	F.	4	May 20	June 5	—	Good.	Severe.	
3	M.	24	May 28	June 24	—	Very good.	Very severe.	Bronchitis. Great nervous prostation.
4	M.	14	May 30	June 10	—	Very good.	Mild.	
5	F.	4	May 31	June 14	—	Good.	Severe.	
6	M.	36	May 31	June 20	—	Good.	Not very severe, but very persistent.	Slight bronchitis.
7	F.	9	June 1	June 16	—	Good.	Mild.	
8	M.	12	June 2	June 18	—	Good.	Very severe.	
9	M.	11	June 2	—	June 14	Good.	Very severe.	Prostration extreme, and bad nursing.
10	M.	5	June 2	June 11	—	Good.	Mild.	
11	F.	24	June 2	—	June 24	Delicate. Nervous system shaken by fits in chilhhood.	Very severe.	Prostration extreme. Hæmorrhage from bowels.
12	M.	16	June 2	June 20	—	Very good.	Severe and very persistent.	Bronchitis (slight).
13	F.	12	June 4	June 20	—	Good.	Severe.	
14	F.	7	June 6	June 18	—	Good.	Mild.	
15	M.	25	June 6	June 24	—	Good.	Very severe.	
16	F.	15	June 6	June 20	—	Good.	Mild.	
17	F.	51	June 10	—	Aug. 31	Stout and often ailing.	Very severe from beginning.	Abscess in temporal region. Progressive emaciation.
18	M.	14	June 10	July 1	—	Good.	Very severe.	
19	F.	4	June 12	June 21	—	Good.	Mild.	
20	F.	5	June 12	June 25	—	Good.	Mild.	
21	M.	10	June 14	June 28	—	Good.	Severe.	Great prostration.
22	F.	26	June 14	June 22	—	Very good.	Severe.	Bronchitis.
23	M.	3	June 14	June 20	—	Very good.	Mild.	
24	F.	18	July 1	July 20	—	Good.	Severe.	Great nervous agitation for several days.

The treatment consisted of—

10 grains of sulpho-carbolate of soda and 2 grains of quinine every three hours, given either in powder or mixture, the quinine in the latter case being dissolved by a few drops of aromatic sulphuric acid.

The dose was diminished in the case of children.

Wine and brandy were given in proportion to the feebleness of the circulation; beef-tea and other nourishments.

The only *treating of symptoms* consisted of turpentine stupes to the abdomen, a bladder of ice to the head when the symptoms indicated. No opium; no treatment of diarrhœa.

Dr. Ligertwood says, "I think the treatment was very successful. There did not seem to be the same tendency to relapse that I have found under other treatment. The diarrhœa, often very severe, never became so exhausting as to call for any special treatment."

Tuberculosis.—Sodium sulpho-carbolate has been administered by me in 121 cases of pulmonary phthisis, and the following is an analysis of the results:—

First stage of the Disease . . .	31 cases.
Decided improvement in . .	19 ,,
Slight improvement in . .	7 ,,
Doubtful	3 ,,
Disease progressed . . .	2 ,,

The objective signs of improvement were cessation of cough, pain, and expectoration, arrest of night sweat, and gain in general signs of nutrition. In one case the local physical signs disappeared entirely. One patient gained in weight $2\frac{1}{2}$ lbs. in 3 weeks; a second, 2 lbs. in 6 weeks; a third, 6 lbs. in 5 weeks; a fourth, 4 lbs. in 8 weeks, and subsequently, 6 lbs. in a second period of 8 weeks; a fifth, after manifesting great improvement left off all treatment, and on observation 3 months afterwards had gained 9 lbs.; a sixth, 6 lbs. in 6 weeks; a seventh, 11 lbs. Three other cases gained each 2 lbs. in 8 weeks. On the other hand, one case manifested sickness and progressive loss of weight, and treatment was omitted.

Second stage of the disease . .	69 cases.
Decided improvement in . .	33 ,,
Slight improvement in . .	16 ,,
No improvement in . . .	17 ,,
Progressive disease in . .	3 ,,

In the favourable cases there was besides subsidence of objective signs, a diminution in the pyrexia, as determined by thermometric observation. One case gained 1 lb. in 6 days; a second, 1 lb. in 14 days; a third, $3\frac{1}{2}$ lbs. in 4 weeks; a fourth, 1 lb. in 8 weeks; a fifth, 3 lbs. in 3 months; a

sixth, 8 lbs. in 2 months; a seventh, 2 lbs. in 3 weeks; an eighth, a steady gain of 5 lbs. On the other hand, one case lost 4 lbs. in 8 weeks; another 6 lbs; and another very rapid case 13 lbs. in the same period; and in a single case the medicine was omitted, as it seemed to cause looseness of the bowels.

Third stage of the disease . . .	21 cases.
Decided improvement in .	12 ,,
Slight improvement in . .	2 ,,
No improvement in . . .	5 ,,
Doubtful	2 ,,

Of these, one case rapidly improved, the patient expressing himself as "feeling a different man." One gained 2 lbs. in 14 days, and on observation 2 months after had gained a further $2\frac{1}{2}$ lbs.; another gained $2\frac{3}{4}$ lbs. in 2 months; a third and fourth, 2 lbs., and three others 3 lbs. in a like period. One patient steadily gained 12 lbs. in two months; then 6 lbs. more; then 4 lbs. in addition; then receded 2 lbs.; and finally 3 lbs. when treatment ceased.

In the tuberculosis of children:

Decided improvement in . . .	8 cases.
Slight improvement in . . .	1 case.
Disease progressing to a fatal result in	1 ,,

In one case local signs entirely disappeared.

In the foregoing cases, though the sodium sulpho-carbolate was almost entirely the only purely medicinal agent administered, cod-liver oil and other dietetic means of treatment were enjoined, so due regard must be had to this fact in estimating the possible value of the salt as a therapeutic agent in phthisis.

(1.) Observation of a number of cases, suffering from that indefinite dyspepsia which is often a precursor of the actual manifestation of tubercle, even when no other remedy was employed showed a gain in nutrition which could not fail to be marked, and which contrasted favourably with the results obtained under methods of purely tonic treatment.

(2.) Where tubercle, according to the evidence of physical signs, was actually deposited in the lung. There were cases showing the *possibility* that in such cases the actual arrest of the morbid process could occur with the restoration of the normal signs evidenced by physical examination. This result could only, however, be exceptional. A general gain in powers of nutrition, when tubercle was actually deposited, was, however, under the treatment by the sulpho-carbolate not exceptional; there was apparently a check placed to the spread of the disease. Certainly, it may be urged that such a result might obtain, without any manifestation of action upon the tuberculous matter, by the improved nutritive conditions of the organism. The question becomes then a comparative one; does the addition of the sulpho-carbolate to the therapeutic agencies in any marked degree influence the results? The answer can only come after extended experience, but the first evidence seems to show that there is an improvement in these cases which does not obtain when ordinary tonic treatment alone is practised.

(3.) When tubercle is undergoing retrograde changes, could the treatment in any marked degree arrest them? The answer must be, in the great majority of instances—No. Nevertheless, there were some instances in which a marked improvement resulted, and there was a manifest effect of arrest of fœtor of breath and of sputum.

II. Sulpho-Carbolates of Alkaline Earth Bases.

Calcium Sulpho-Carbolate.—Quite apart from any faculty as an indirect means of administering carbolic acid, this salt has a property which renders it peculiarly valuable for administration in certain diseases. In cases in which the osseous system is deficient in lime salts, it has always been a problem to find a lime salt which shall be readily absorbed by the economy. The difficulty with regard to the ordinary medicinal lime preparations is their insolubility. Calcium-carbonate is not sensibly soluble in water: the phosphates are insoluble; and a pint of water at 60° F. will only dissolve

11 grains of calcium hydrate. The calcium sulpho-carbolate, on the other hand, is perfectly soluble *in its own weight of water*, and it can be administered and absorbed with the greatest ease. Calcium sulpho-carbolate has been administered, combined with ordinary chalk mixture, in the treatment of the diarrhœa occuring in unhealthy children. The patients concerning whom these results were recorded were out-patients of the North Eastern Hospital for Children; these almost entirely were dwellers in the poorest and most insalubrious parts of the East of London, Shoreditch, Bethnal Green, &c. The duration of the diarrhœa was manifestly controlled. In cases of rachitis and wasting, however, where there was extremely depressed nutrition, there was the chief manifestation of good results.

A table comprising the particulars of 22 of these cases is inserted in Beale's "Archives of Medicine," No. xvii., pp. 69, 70. My colleague, Dr. W. Bathurst Woodman, has independently observed and carefully tabulated 88 cases of rickets, treated with the sulpho-carbolate of calcicum, at the North Eastern Hospital for Children. The following is an analysis of the results :—

"53 cases (besides the 6 who died) received more or less benefit. 15 cases exhibited very marked benefit. In all the cases benefit is tested by amelioration of all the general symptoms, increase of weight and strength, &c. No bad symptoms could ever be traced to the drug. 29 cases ceased attending—it is probable this was partly due to the sulpho-carbolate being administered in plain water only, without any mixture of colouring agent, or any other addition—except in the cases noted. The medicine appeared not to have any effect upon diarrhœa in most cases."

I quite endorse the conclusion that the calcium sulpho-carbolate *per se* has no effect in restraining diarrhœa. I even think that in large doses it acts as a mild laxative; but I have certainly obtained evidence that it has a beneficial influence when combined with an astringent or with ordinary chalk mixture in the treatment of diarrhœa. The

vitiated secretion of the bowels seems to be changed and deprived of its irritant character. In the *chronic diarrhœa of unhealthy children* I have observed the effects of the treatment in 23 cases. Of these 14 recovered; 5 improved (3 greatly); 3 cases were doubtful, and one died. The average period of treatment before complete recovery was 12½ days.

In the treatment of *rachitis* I have obtained the following results:—In 39 typical cases, complete recovery took place in 9; great improvement in 16; improvement in 8; no effect in 6. The average duration of treatment antecedent to complete recovery was 46 4-9 days; the average period in those which manifested "great improvement" was 31 9-14 days; in those manifesting "improvement" 19 5-8 days; in those showing no effect 27 days.

In a very valuable and interesting communication on rickets, by Dr. C. Currie Ritchie, of Manchester,* the author states that he has employed the calcium sulpho-carbolate as recommended by me in 26 cases, for periods varying between 6 weeks and 5½ months. He adds, "I regret to say, however, that I have not met with the successful results obtained by Dr. Sansom, as in only two cases did any real benefit seem to follow the administration of the sulpho-carbolate; and in these the hygienic and dietetic conditions were so glaringly vitiated, that I am convinced the improvement was justly due, not to the drug but to the improved regimen." But Dr. Ritchie has not understood my premisses. I in no wise assert the calcium sulpho-carbolate to be a remedy for rickets in the sense of a specific. Like himself I recognise the disease to be complex—an aggregate of faulty conditions. A deficiency of lime salts in the bones in cases of rickets is, I presume, conceded by all of us. I have urged that the lime preparations usually employed, from their deficient solubility, allow of the absorption, and, consequently, of the communication, of the element in proportions too feeble to be of pronounced

* "Clinical Observations on Rickets;" Medical Times and Gazette, January 7, 1871, p. 9.

practical effect. The calcium sulpho-carbolate is so soluble and itself so innocuous, that it can freely supply the blood with the deficient lime. In all cases, however, I am accustomed to treat, not this single want, but the wants of the system generally, and to combat errors of regimen and errors of assimilation. In many cases, as I have formerly said, I have combined the administration of cod-liver oil with the treatment. That the calcium sulpho-carbolate itself is capable of supplying one of the great wants of the system in the condition of rachitis is, I think, sufficiently proved by the facts, that in 25 of the cases which I have recorded as manifesting either complete recovery or great improvement, no other medicinal agent save the sulpho-carbolate was administered; nor was cod-liver oil nor any special dietetic agent employed in these cases. The progressive improvement could not fail to be noted; in several of the cases the children were prior to treatment absolutely helpless, yet the bones became gradually firmer, and at the end of treatment the children were well able to run alone; there could with scarcely any possibility be a misinterpretation of the signs.

III. Sulpho-Carbolates of the Metals.

The *zinc and copper salts* have been employed in aqueous solution as lotions for the treatment of wounds by Professor John Wood. Thus employed, in proportions of 3 to 5 grains to the ounce of water, Mr. Wood considers they manifest good antiseptic qualities. Their action is two-fold: partly by the disintegrating action of the vital or semi-vital fluids, whereby the carbolic acid is liberated, partly by the inherent antiseptic quality of the metallic salts. Wounds are thus kept clean and free from smell. Mr. Wood has employed the solutions as injections in gonorrhœal and other discharges, and as a dressing for superficial venereal sores.* Like testimony comes from various American surgeons.†

* "On the Topical Treatment and Dressing of Wounds;" Practitioner, October, 1868, p. 208.

† "American Journal of Pharmacy." See Pharmaceutical Journal, July 16, 1870.

Iron Sulpho-Carbolate.—This has been largely employed in the treatment of affections in which other iron salts have been recommended. The dose for adults has been 10 to 15 grains. In children the dose has been 2 to 3 grains after the first year. The chief value of the salt has been seen in impetigo and the skin affections of ill-nourished children. In tubercular and pretubercular affections it has manifested no marked benefit, the results being far inferior to those of the administration of the sodium salt. In external scrofulosis it seems to have been of advantage.

APPENDIX.

ACIDUM CARBOLICUM. Carbolic Acid. *Synonym*, Phenic Acid. $HOC_{12}H_5O$, or HC_6H_5O. An acid obtained from coal-tar oil by fractional distillation and subsequent purification.

Characters and Tests.—In colourless acicular crystals, which at a temperature of 95° become an oily liquid, having a strong odour and taste resembling those of creasote, which it also resembles in many of its characters and properties. Its specific gravity is 1·065, boiling-point 370°. The crystals readily absorb moisture on exposure to the air, and they are thus liquefied. The acid, however, is but slightly soluble in water, but it is freely soluble in alcohol, ether, and glycerine. It does not redden blue litmus-paper. A slip of deal dipped into it and afterwards into hydrochloric acid and then allowed to dry in the air acquires a greenish-blue colour. It coagulates albumen. It does not affect the plane of polarisation of a ray of polarised light.

Preparation.—*Glycerinum acidi carbolici.*—1 part in 6 by weight.

(*British Pharmacopœia*).

FORMULÆ.

1.—Liquefied Carbolic Acid.—A. Calvert's purest (No. 1) acid liquefied by placing the bottle containing it in hot water, 9 parts; water, 1 part; mix well. (CALVERT).

B. Pure carbolic acid, 15 parts; alcohol, 1 part; mix well. This keeps fluid at all ordinary temperatures. (AUTHOR).

For many purposes, especially for dispensing, it is convenient to keep the acid in a liquid form; otherwise the crystals must be melted by heat each time that the acid is employed.

2. Solution of Carbolic Acid in Water.—To obtain uniform solution, it is better to shake the carbolic acid with four times its bulk of hot water, and then to add a sufficiency of cold water. Or, the carbolic acid may be first mingled with alcohol, which causes more ready solubility before the addition of cold water. Water will not dissolve more than one-twentieth of its bulk of carbolic acid.

3. **Alcoholised Carbolic Acid** (*Acide Phénique Alcoolisé*).—Alcohol (90°); crystallised carbolic acid, equal parts; mix, and keep in a well-stoppered bottle. Used for making carbolised solutions, &c. Being more fluid than carbolic acid, it more readily penetrates the tissues. Useful in poisoned wounds, for application to small-pox pustules, &c. (LEMAIRE).

4. **Etherised Carbolic Acid** (*Ether Phéniqué*).—Sulphuric ether, 100 parts; carbolic acid, 1 part. Used for insufflation in catarrh of the Eustachian tube. (LEMAIRE).

5. **Carbolised Vinegar** (*Vinaigre Phéniqué*).—Ordinary vinegar, 4 parts; carbolic acid, 1 part; mix. For use instead of aromatic vinegar as disinfectant, &c. (QUESNEVILLE).

6. **Glycerinum Acidi Carbolici.**—Carbolic acid, 1 oz.; glycerine, 4 fluid ozs. Rub them together in a mortar until the acid is dissolved. (*British Pharmacopœia*).

7. **Carbolised Glycerine** (*Glycérine Phéniquée*).—Pure glycerine, 100 parts; carbolic acid, 1 part; mix. For impetigo, chronic eczema, lichen, prurigo, and pemphigus. (LEMAIRE).

8. **Syrup of Carbolic Acid** (*Sirop d'Acide Phénique*).—Simple syrup, 100 parts; crystallised carbolic acid, 1 part; mix. (CHAUMELLE).

9. **Carbolic Acid Liniment.**—For counter-irritation. A. alcohol, 50 parts; carbolic acid, 1 part; mix. (LEMAIRE).

B. Olive oil, 7 parts; carbolic acid, 1 part. (AUTHOR).

10. **Compound Disinfectant Solution.**—Water, 1000 parts; carbolic acid, 10 parts; sulphate of zinc or sulphate of iron, 3 parts; mix. Carbolic acid has no chemical action on sulphuretted hydrogen or carbonate of ammonia; when it is employed alone as a disinfectant deodorisation does not take place till the gases have disappeared by diffusion. The sulphates change the sulphuretted hydrogen into sulphides, and the carbonate of ammonium into metallic carbonate and ammonium sulphate, all inodorous compounds. (LEMAIRE).

11. **The Süvern Deodorant.**—Good quicklime, 1½ bushels put in a cask, slaked, and well stirred; coal-tar, 10 lbs.; mix thoroughly; then add magnesium chloride, 15 lbs. dissolved in hot water. Mix again and add hot water until the mass is liquid enough to drop slowly from a stick plunged into it and then withdrawn. The magnesium chloride forms deliquescent calcium chloride, magnesia being liberated; this prevents caking and adherence to pipes, which is a defect when lime alone is used. (PARKES).

12. **Carbolised Earth** (*Terre Coaltarée*).—Common loam passed through a sieve, 100 parts; coal-tar, 2 parts; mix intimately. Disinfectant for crops and for destruction of noxious insects. (LEMAIRE).

13. **Solution of Carbolic Acid for the Toilette.**—Crystallised carbolic acid, 10 parts; essence of millefleurs, 1 part; tincture of "quillaya saponaria," 50 parts; water, 1000 parts; mix. The saponine replaces soap with advantage. The above should be employed diluted with ten times its bulk of water for disinfecting the skin; for washing the hands after any risk of contagion or inoculation, &c. (LEMAIRE).

14. **Tincture of Saponine**, as used in the forcgoing preparation, is thus made :—Bark of "quillaya saponaria," 1 part; alcohol (90°), 4 parts; heat to ebullition and filter. (LE BEUF).

15. **Carbolised Water for the Teeth.**—Water, 1000 parts; essence of mint, 2 parts; tincture of saponine, 50 parts; pure carbolic acid, 10 parts; mix. A dessert spoonful in a quarter of a tumblerful of water serves as an excellent preparation for cleaning and preserving the teeth. (LEMAIRE).

16. **Carbolised Ointment.**—Purified lard, 100 parts; carbolic acid, 1 part; mix. Considered of some service in skin affections, but modified as it is by the fat, it cannot replace the aqueous solution of carbolic acid. (LEMAIRE).

17. **Carbolised Amylaceous Ointment.**—Pure starch, 3 parts; hot water, 20 parts; mix in the ordinary way (the starch being made first into a paste with cold water and then hot water added) to a stiff consistence; then add olive oil, 1 part; glycerine, 3 parts; carbolic acid, 1 part, and thoroughly mix in a mortar. When cool, this is a soft jelly which can easily be applied as ordinary ointment. It is much more efficacious than one the basis of which is entirely fat, and it is an agreeably cool application. Mr. John Lees, of 2, Upper Street, N., has made several satisfactory and agreeable preparations with this as a basis. (AUTHOR).

18. **Carbolised Oil.**—A. Crystallised carbolic acid, 1 part; boiled linseed oil, 4 parts; dissolve. (LISTER.)

B. Pure carbolic acid, 1 part; olive oil, 6 parts. Olive oil is better than linseed oil as a vehicle, as the latter is more prone to oxidation. (CALVERT).

19. **Carbolised Putty.**—Carbolised oil about 6 tablespoonfuls. Common whitening (chalk) sufficient to make a firm paste. (LISTER).

20. **Antiseptic Lead Plaster.** Olive oil 12 parts (by measure); Litharge (finely ground), 12 parts (by weight); Bees'-wax, 3 parts (by weight); Crystallised carbolised acid, 2½ parts (by weight). Heat half the olive oil over a slow fire, then add the litharge gradually, stirring constantly till the mass becomes thick or a little stiff; then add the other half of the oil, stirring as before, till it becomes again thick. Then add the wax gradually, till the liquid again thickens. Remove from the fire, and add the acid, stirring briskly till thoroughly mixed. Cover up close and set aside, to allow all the residual litharge to settle; then pour off the fluid, and spread upon calico to the proper thickness. The plaster made in this way can be spread by machine, and kept rolled in stock; and, if in a well-fitting tin canister, will retain its virtues for any length of time. (LISTER).

21. **Antiseptic Lac-Plaster.**—Shellac, 3 parts; crystallised carbolic acid, 1 part. Heat the lac with about one-third of the carbolic acid over a slow fire till the lac is completely melted; then remove from the fire and add the remainder of the acid, and stir briskly till the ingredients are thoroughly mixed. Strain through muslin, and pour into the machine for spreading plaster; and, when the liquid has thickened by cooling to a degrce asccrtained by expcriencc, spread to the thickness of about one-fiftieth of an inch. Afterwards, brush over the surface of thc plaster lightly with a solution

of gutta-percha in about 30 parts of bisulphide of carbon. When the sulphide has all evaporated, the plaster may be piled in suitable lengths in a tin box, without adhering, or rolled up and kept in a canister. (LISTER).

22. **Antiseptic Cere-Cloth.**—Cloth or thin calico is saturated with cerate (made after the following formulæ) by simply drawing a portion through it while in a fluid state, or in pieces of any length and width, by rolling, by means of a machine, the calico over cylinders containing cold water, as fast as it has taken up the cerate.

(1.) **Strongest Cerate.**—Calvert's pure carbolic acid, liquefied, 3 fluid ozs.; olive oil (coloured red with alkanet root to distinguish the cerate), 1½ fluid ozs.; yellow wax liquefied, 1½ fluid ozs.; paraffin, liquefied, 6 fluid ozs. Mix. (2.) **Medium Strength.**—Pure carbolic acid, 2 fluid ozs.; olive oil, 2½ fluid ozs.; yellow wax, 2½ fluid ozs.; paraffin, 5 fluid ozs. Mix. (3.) **Weakest.**—Pure carbolic acid, 1½ fluid ozs.; olive oil, 1 fluid oz. and 6 drms.; white wax, 1 fluid oz. and 6 drms.; paraffin, 7 fluid ozs. Mix. (LUND).

23. **Antiseptic Muslin Gauze.**—Paraffin, 16 parts; resin, 4 parts; crystallised carbolic acid, 1 part. Melt together. Cheap muslin gauze is dipped in the melted mass, and well wrung or pressed while hot. A good substitute for oakum as an antiseptic covering for wounds, unirritating to the most sensitive skin, highly retentive of the acid and almost destitute of odour. It should when used be folded in about eight layers. It loses the paraffin and resin when washed in boiling water, so the same gauze may be used repeatedly. (LISTER).

24. **Protective** against local irritating effects of carbolic acid in antiseptic dressings. Varnish oiled silk on both surfaces with copal varnish. When dry brush over with a mixture of starch and dextrine to give it a film of material soluble in water, so that it becomes uniformly moistened when dipped into antiseptic lotion. When not at hand common oiled silk may be used as a substitute for it, if smeared with an oily solution of carbolic acid, and used in two layers to make up for its inferior efficiency. (LISTER).

25. **Antiseptic Adhesive Plaster.**—Dip ordinary strapping in hot solution of carbolic acid, made by mixing 1 part of 1 to 20 lotion, with 2 parts of boiling water. Will adhere to a moist skin, so that it may be applied under spray when advisable. (LISTER).

26. **Carbolised Powders.**—Pure liquefied carbolic acid, 5 parts; alcohol, 5 parts. Mix. Add by degrees 100 parts of one of the following powders—lycopodium, starch, charcoal, plaster of paris. The proportion of carbolic acid can be increased or decreased as desired. (AUTHOR).

27. **Antiseptic Catgut Ligature.**—Catgut of the thicknesses required is to be kept steeped in carbolised olive oil (1 part in 5) with a very small quantity of water diffused throughout it. The small proportion of water present renders the gut supple, and so changes it that it may be transferred to a watery solution at the commencement of an operation, and thus kept supple without swelling or perceptibly changing in strength or bulk. (LISTER).

28. **Aceto-Carbolic Solution for Tinea and Scabies.**—Acetic acid (pyroligneous) 8°, 20 parts; pure carbolic acid, 5 parts; water, 75 parts. Mix the two acids and add the water. The acetic acid favours penetration through the epidermis. For *tinea*, apply the liquid once a day over the

diseased parts by means of a brush. For *scabies*, sponge all the parts. The clothes, &c., of the affected individual should also be treated with the liquid. (LEMAIRE).

29. Carbolised Gargle for Diphtheria Tonsillitis, &c.—Carbolic acid, 20 minims; acetic acid, ½ a drachm; honey, 2 fluid drachms; tincture of myrrh, 2 fluid drachms; water, to 6 fluid ounces. The carbolic and acetic acids to be well shaken together before the other ingredients are added.

(CHARLES SEDGWICK, JUN.)

30. Carbolised Mixture for Zymotic Diseases.—Carbolic acid, acetic acid, of each, from 1 drachm to 1½ fluid drachms; tincture of opium, 1 fluid drachm; chloric ether, 1 fluid drachm; water to 8 fluid ozs. A tablespoonful every four hours until the fever has subsided. (DR. ALEX. KEITH.)

31. Mixture of Quinine and Supho-carbolate of Sodium.—Quinine sulphate, 1 grain; sulphuric acid, 5 minims. Dissolve and add to solution of sodium sulpho-carbolate 20 grains, in water one fluid oz. (AUTHOR).

Plate I.

FIG. 1.

Bacteria.

FIG. 2.

Vibrio spirillum, and Monas lens (*b*, *b*, *b*.)

FIG. 3.

Minute Bacteria, germinating and multiplying. × 1800. (*Beale.*)

FIG. 4.

Very Minute Bacteria in outline. × 2000. (*Beale.*)

FIG. 5.

Supposed spontaneous development of ovum. Spherical aggregations of granules and appearance of zones. (*Pouchet, Pennetier.*)

FIG. 6.

Appearance of limiting membrane; Regular distribution of granules within spheres. (*Pouchet, Pennetier.*)

Plate II.

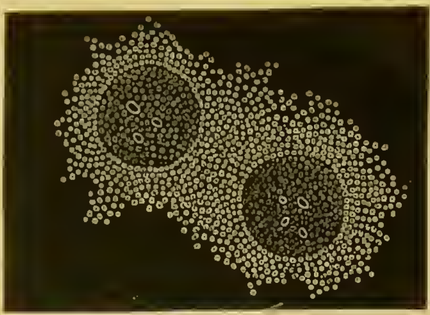


FIG. 7.

Supposed spontaneous formation of ovum, continued. Differentiation of internal organs. (*Pouchet, Pennetier.*)

FIG. 8.

The organism endowed with instinctive movements. (*Pouchet, Pennetier.*)

FIG. 9.

The free Microzoon. (*Pouchet, Pennetier.*)

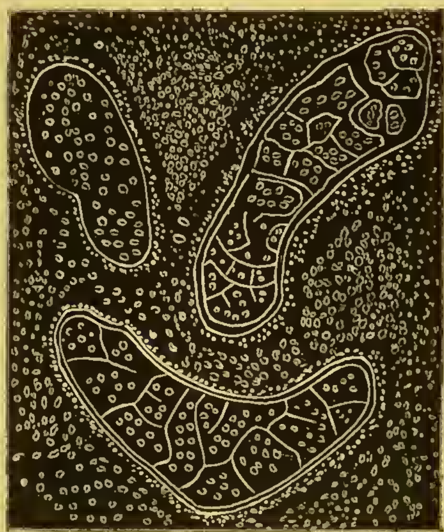


FIG. 10.

Supposed heterogenic evolution of unicellular organisms. (Diagrammatic, after *Bastian.*)

FIG. 11.

Supposed heterogenic evolution of spores of fungi. (Diagrammatic, after *Bastian.*)

Plate III.

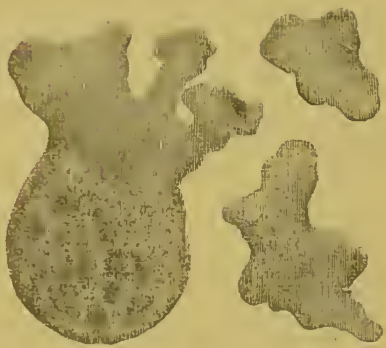


FIG. 12.

Minute *Amœbæ* in active movement. Smallest less than 1-10,000th inch in diameter. × 5000. (*Beale.*)

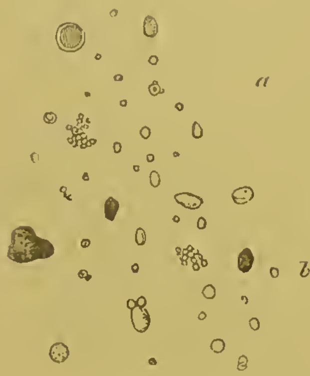


FIG. 13.

Corpuscles obtained from atmospheric air, heated by (*a*) solution of potash; (*b*) aqueous solution of iodine. (After *Pasteur.*)

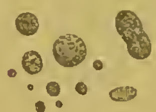


FIG. 14.

Most minute germs of fungi visible under the 1-50th. Smallest much less than 1-100,000th inch in diameter. (*Beale.*)

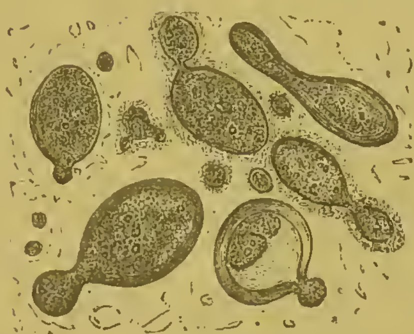


FIG. 15.

Growing yeast-cells and minute germs. × 2800. (*Beale.*)

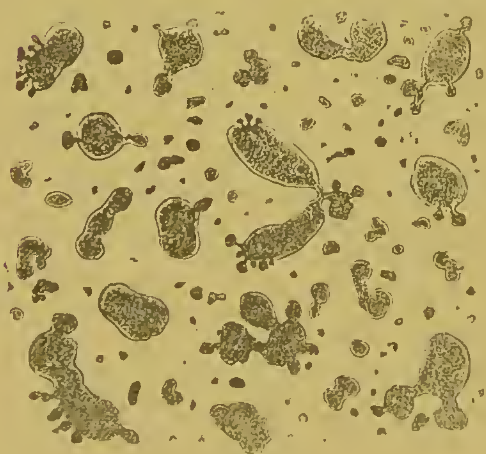


FIG. 16.

Growing yeast-cells, showing buds from bioplasm and mode of detachment to form new cells. × 1300. (*Beale.*)

FIG. 17.

Fructification of *Penicillium crustaceum.* × 160. (After *Hallier.*)

Plate IV.

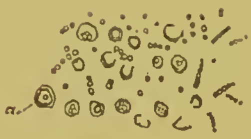


FIG. 18.

Spores of *Penicillium crustaceum* bursting in water and setting free their contained particles, which unite in rows or chains. (After *Hallier*.)

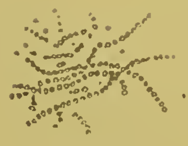


FIG. 19.

Union of particles to constitute *Leptothrix* chains. (*Hallier*.)

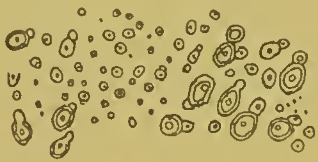


FIG. 20.

Formation of *Cryptococcus cerevisiæ*, showing intermediate stages between the minute particles and the complete double cells. (After *Hallier*.)

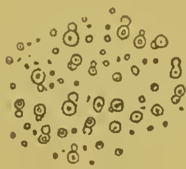


FIG. 21.

Oil-ferment (*Cryptococcus*) from *Penicillium* spores sown in poppy oil. (After *Hallier*.)

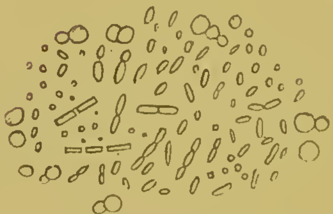


FIG. 22.

Milk ferment (*Arthrococcus*), from *Penicillium* spores sown in milk. (After *Hallier*.)

FIG. 23.

Milk ferment, showing aërial growth. × 225. (*Author*.)

FIG. 24.

Acetic ferment (*Arthrococcus*), developing from *Penicillium* spores.

FIG. 25.

Acetic ferment, from the surface of stale beer. × 225. (*Author*.)

Plate V.

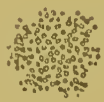


Fig. 25*a*.

Micrococci of putrefaction.
(After *Hallier*.)

Fig. 26.

Aspergillus primigenius (seventh day). In experiment strictly parallel, in atmosphere containing carbolic acid, there was no vegetable growth whatever. × 75.
(*Author.*)

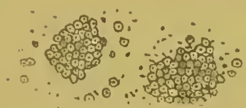


Fig. 25*b*.

Gallic acid ferment.
(After *Hallier*.)

Fig. 27.

Aspergillus polymorphus, found at one spot in the soil, imperfectly exposed to carbolic acid vapour. × 225.
(*Author.*)

Fig. 28.

Fungi, grown in solution of strychnine. × 225. (*Author.*)

Plate VI.

FIG. 29.
Achorion Schönleinii, from case of tavus; *a*, hair broken near root; *b*, separated hair fibres; *c*, altered Epithelium from skin; *d*, mass of sporules of fungus; *e*, sporules and thalli separate. (*Beale.*)

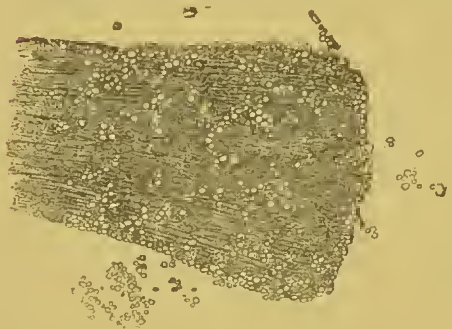


FIG. 30.
Tricophyton tonsurans in root of hair in *Tinea tonsurans*. After Tilbury Fox. (*Beale.*)

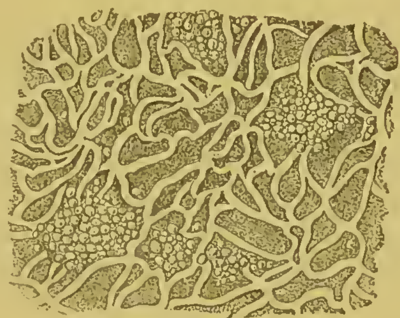


FIG. 31.
Microsporon in *Tinea versicolor* (Chloasma). After Tilbury Fox. (*Beale.*)

FIG. 32.
Chionyphe Carteri; *a,a*, germinating sporidia; *b,b*, commencement of spore-cells (nucleated); *c*, nucleus and spore contents further advanced; *d*, multiplication of contents of spore-cell; *e*, spore and sporidia formed; *f*, spore bursting; *g*, sporidia more highly magnified; *h*, spore embraced by filaments. A, filament composed of cells with nucleus at the end of each. B, felt-like form of fungus; *a*, filamentous layer; *b*, layer of spores; *c*, filamentous layer below. (*Beale.*)

Plate VII.

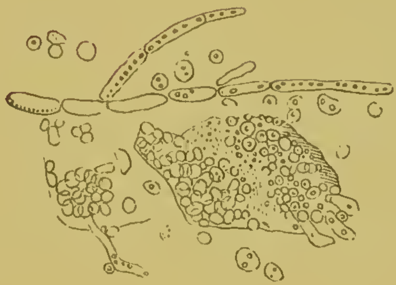


FIG. 33.

Oïdium Albicans. After Robin. (*Beale.*)

FIG. 34.

Leptothrix formed in solution of sugar from *Leptothrix* from the mouth. (After *Hallier.*)

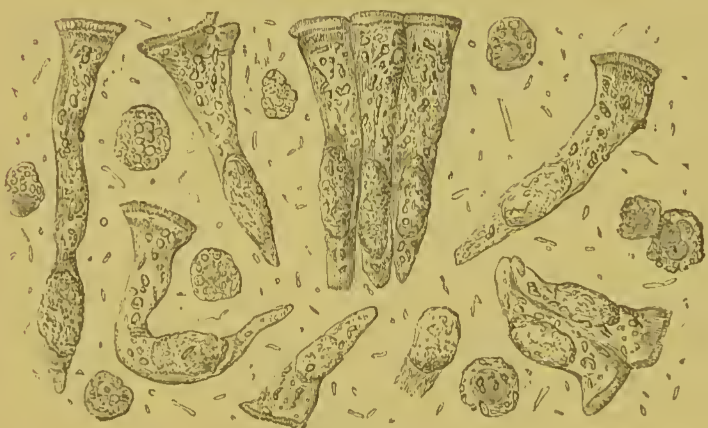


FIG. 35.

Bacteria and Bacteria germs, within and amongst epithelial cells from jejunum of a child who died of cholera. × 700. (*Beale.*)

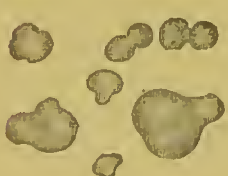


FIG. 36.

Particles from vaccine lymph, manifesting active movements. × 5000. (*Beale.*)

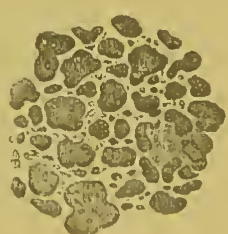


FIG. 37.

Minute particles of bioplasm (contagium?) from fibrous tissue of the skin beneath eruption. Cattle Plague. × 1800. (*Beale.*)

Plate VIII.

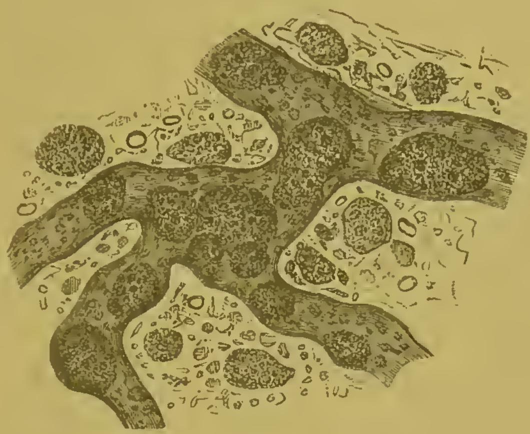


Fig. 38.

Large masses of bioplasm and minute bioplasts (disease germs) in capillary vessels from surface of villus. Cattle Plague. × 700. (*Beale.*)

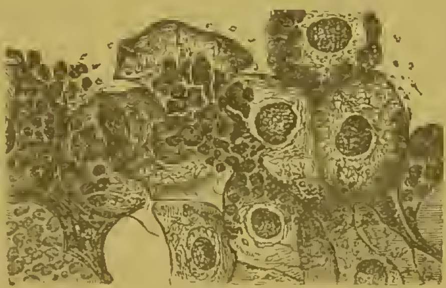


Fig. 39.

Cells of cuticle under scab, invaded by growing and multiplying particles of bioplasm (contagium ?) Cattle Plague. × 700. (*Beale.*)

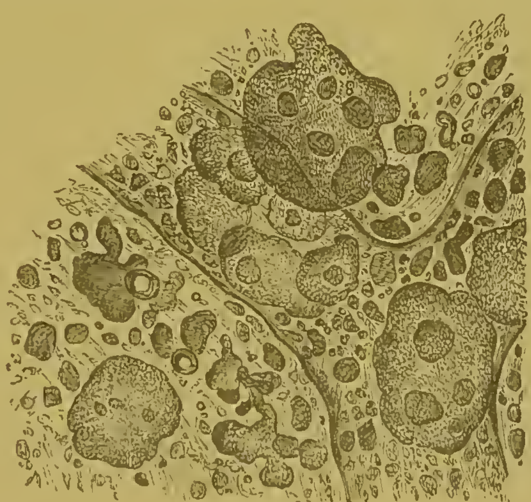


Fig. 40.

Large and small masses of bioplasm. Capillary from surface of villus. Case of Cattle Plague in which complete disorganisation had occurred. × 2800. (*Beale.*)

Plate IX.

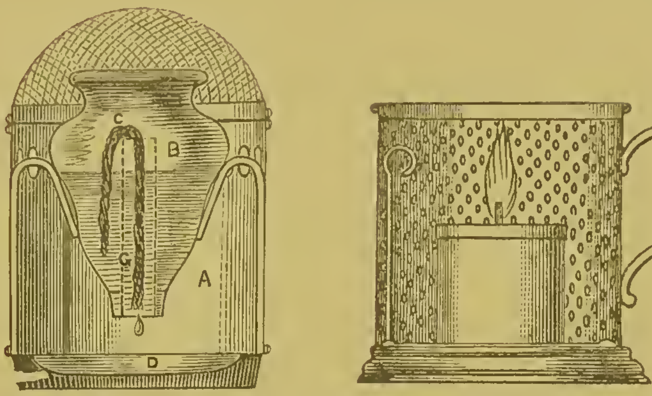


FIG. 41.

Savory and Moore's Vaporiser for Carbolic Acid.

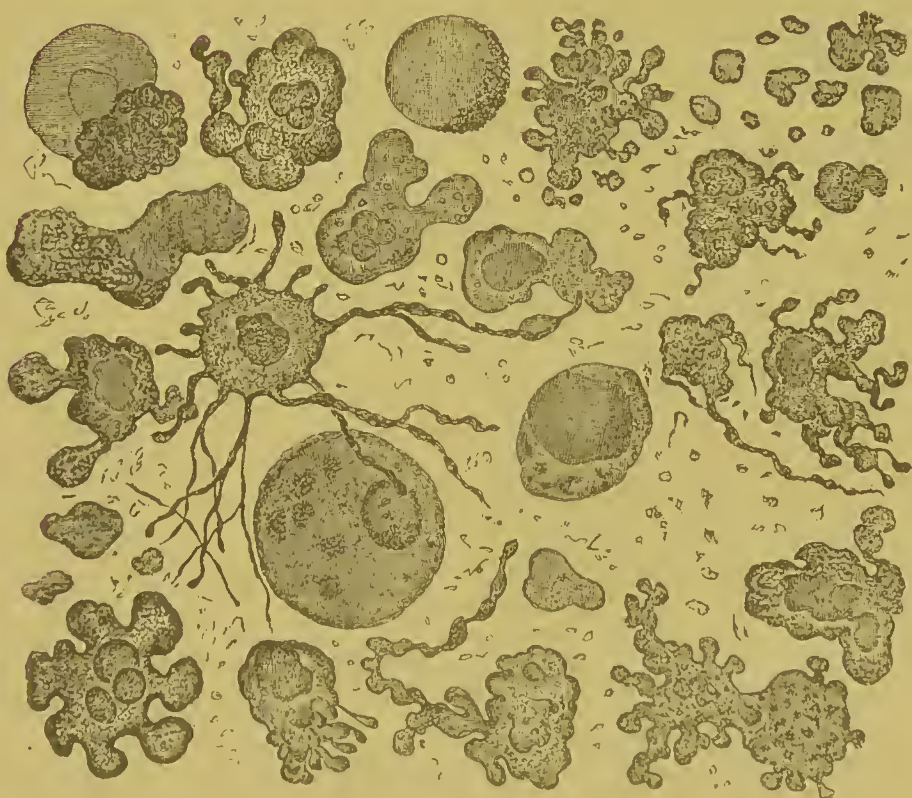


FIG. 42.

Pus corpuscles, manifesting active movements and changes of form. From the bladder in a state of inflammation.
(*Beale.*)

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